

Agricultural Production

Organic and Conventional Systems



Okoro M. Akinyemi

VISIT...

LANZAROTE
Caliente.COM

Agricultural Production

Organic and Conventional Systems

Agricultural Production

Organic and Conventional Systems

Okoro M. Akinyemi
Kassel
Germany



Science Publishers

Enfield (NH)

Jersey

Plymouth

CIP data will be provided on request.

SCIENCE PUBLISHERS

An imprint of Edenbridge Ltd., British Isles.

Post Office Box 699

Enfield, New Hampshire 03748

United States of America

Website: <http://www.scipub.net>

sales@scipub.net (marketing department)

editor@scipub.net (editorial department)

info@scipub.net (for all other enquiries)

ISBN 978-1-57808-512-5

© 2007, Copyright reserved

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior written permission.

This book is sold subject to the condition that it shall not, by way of trade or otherwise, be lent, re-sold, hired out, or otherwise circulated without the publisher's prior consent in any form of binding or cover other than that in which it is published and without a similar condition including this condition being imposed on the subsequent purchaser.

Published by Science Publishers, Enfield, NH, USA

An imprint of Edenbridge Ltd.

Printed in India.

Dedication

This book is dedicated to my late mother, *Mrs. Ameyi Alice – Okoro*, who worked diligently and provided me constant love and encouragement to achieve my noble aspiration.

Foreword

This book examines production efficiency and economic benefits of agricultural production, comparing both organic and conventional systems with specific emphasis to some crops and animal production. Most of the material in this book has been collected from already existing books of other authors and essayists, as well as personal experience gained during the author's teaching career.

It dwells on the production systems with special emphasis on some vegetable crops as well as cattle and chicken breeding. Diseases and pest outbreaks are looked into with a view of recommending the appropriate methods of control. Definition of land and its uses are discussed. Factors affecting soil formation and methods of replenishing lost nutrients are enumerated in an attempt to educate students and farmers on the modern techniques of retaining soil nutrients without environmental destruction. Experiments conducted on soil to investigate the effects and factors affecting nutrients mineralization have been described. Descriptions of forest trees have been given to explain their roles in economic expansion. Methods of planting, rules and regulations implemented by communities, states and countries are also discussed.

This book critically reviews the effects of agricultural chemicals on soil organisms and other agricultural practices. A case study for replacing chemicals with ecologically sound alternatives and comments on how this might be implemented, has been put forward. The framework for considering these aspects emphasizes a normative, rather than an extrapolative approach, and collaboration with nature to reach optimal levels of productivity.

The major aspects of agricultural production are presented in 12 chapters. Chapter 1 reviews organic agricultural practices, and Chapters 2 and 3 focus on agricultural sustainability and factors affecting land tenure systems and uses. Chapters 4 and 5 examine the effects of chemicals on agricultural practice and pests and disease control. Chapters 6 and 7 present strategies of weed management and plant nutrients utilization. Chapters 8 and 9 discuss agricultural mechanization and methods of

vegetative propagation. Chapter 10 is a thorough guide to some vegetable production, while Chapter 11 emphasizes strengths and constraints in marketing organic fruits. Chapter 12 portrays an overview of livestock production. A separate section is included at the end which provides meaningful recommendations on production practices and quality control methods for the benefit of the readers.

Alexandra Angela Baltatu

Preface

Organic farming is essentially an agricultural management practice that avoids usage of pesticides, fertilizers produced synthetically, livestock feed additive, etc. Organic farming is characterized by the use of crop rotation, mulch materials, and composting materials. The foundation of organic farming lies in the health of the soil. A fertile soil provides essential nutrients to crop plants and helps support diverse and active biotic communities. Strategic transitional methods that are required for the farmer to build up crop nutrients in organic agriculture are crop rotations, animal and green manures, and cover cropping systems. Cover crops maintain the nutrient balance in the soil and on the other hand, promote biological pest control to maintain soil balance and reduction of pest population and weeds.

Currently, organic agriculture is practised in almost all parts of the world, and its share of agricultural land and farms is growing. The total organically managed area as of 2004 is more than 24 million hectares world-wide. The essence of organic growing is soil management and fertility maintenance. Many farmers do not understand the phenomena behind organic agriculture and soil. The primary goal of organic agriculture is to feed the soil but not to feed the plant. The food given to the soil will nourish the plant better than nutrients can.

Organic farmers have seized the opportunity provided by the potential positive qualities of organic products. For many farmers, the primary reason for switching to organic production systems is to improve (1) the process and quality of food produced, and (2) practices involved (Vaarst et al., 2004). Private and organic researchers support farmers' aspirations in many countries, and advisory organizations combine the farmers' objectives with the overall organic goals in a close-knit circle of shared interests and ambitions (Vaarst and Hovi, 2004).

With the current development of organic certification and legislation, (Organic Standards), the control of quality produce has shifted from farmers and producers to certification bodies and to the legislatives. It has been suggested that the development of goals and principles has also shifted from farmers, with the onus being well informed to the consumers (Lockeretz and

Lund, 2003). Farmers are expected to focus more on process quality as the primary consumers' interest is product quality. Several surveys revealed that consumers have some interest in process issues, as this calls for hazard analytical for critical control point (HACCP).

Biodynamic agriculture was the first ecological farming system which arose from the effect of commercial fertilizers. Yet it remains largely unknown to the modern farmers and land-grant university systems. However, the contribution of biodynamics to organic agriculture is significant (Diver, 1999).

When the development of organic agriculture began, it was Rudolf Steiner, an Austrian Scientist and a philosopher, who understood the need for naturalness in agricultural production. He put forward a theory that was adopted by H. Pfeiffer at the end of the 1920s in Germany, Switzerland, Denmark, England and Netherlands; he is acknowledged as the initiator of biodynamic farming.

Currently, the organic movement is represented commercially by Demeter in Germany and other countries. However, it differs from several other movements in today's world and in a certain degree of idealism, a philosophical twist, as well as specific cropping methods, linking agricultural activities to the lunar and astral cycles.

At the end of the World War II (1940s), this movement led to formation of "The Soil Association" in England. The Soil Association (based on the theory of Sir Albert Howard in 1940), carries out research and development. (Viandes, 1999).

In 1930, the Swiss politician H. Müller gave impetus to this new movement. His objectives were directed at the economic, social and political concern as they envisioned autarchy of the farmer, and towards more direct and less cluttered connections between the production and consumption stages (Viandes, 1999). Austrian doctor Hans Peter Rush also adapted this idea and incorporated it in a manner which was based on maximum utilization of renewable resources in 1930s.

In the 1950s, the expansion and dual polarity of organic agriculture began to spread. It finally called for organic farming, which later started in France. Since the beginning of the organic movement in the 1950s, consumers have become aware of the constant growth regarding food and its effect on human health. In 1968, the ideological upheaval in France and growing sensitivity to ecological issues started spreading. This has now spread to the whole of Europe. Besides, EU's regulations stipulate that from 2012 the use of chemical substances (in poultry) will not be allowed in the European Union. The social and cultural context and general propagation

of ideas has also exerted a strong influence throughout many steps in the development of organic farming in today's production systems.

In the 1970s, protest movements and alternative life styles of organic farming led to a definite change in the farming practices, resulting in new ideas, and significant sociological transformations.

Modern-day ecological movement has also gained momentum and benefited from an additional boost due to the oil crisis of 1973. It was the epoch of the "return to the earth" and life in alternative communities (Viandes, 1999). The Soil Association has designed a logo to identify the product they certify. The formulation specifications and quality control norms of Soil Association give legal binding guarantee to consumers on organic products. In France, farmers trade syndicates have joined hands to form federations (Fédération Nationale d'Agriculteurs Biologiques) in an attempt to promote organic agriculture worldwide. Major national organic farming organizations joined forces in the formation of IFOAM (International Federation of Organic Agriculture Movements) in the early 1980s.

Acknowledgement

This book epitomizes a perfect creation—the result of the collective efforts of committed minds. I, therefore, owe a debt of gratitude to a number of people for their collaborative work towards the completion of this book.

Firstly, my sincere gratitude goes to Prof. Dr. Peter von Fragstein, Prof. Dr. Holger Wildhagen, Ms. Penelope Pohlner, James Thompson, Mary Catherine Apolot (Schulz), Mrs. Kalpana Sharma and Mr. Dandamaraju Srikanth, for Proofreading the relance pages that requires both Scientific and linguistic skills. I also express my sincere thanks and appreciation to: PG; Dr. Gerold Rahmann, Head of Institute of Organic Farming (OEL) and Federal Agricultural Research Centre (FAL), Germany, and Prof. (Dr.) Ute Knierim, Department of Farm Animal Behaviour and Husbandry, University of Kassel, for providing all the assistance and guidance during my studies at the University of Kassel.

I am extremely grateful to the following people for their moral support and encouragement during my studies at the University of Kassel: (Prince) S.A. Okoro, the former mayor, Egor Local government, Edo State, Nigeria, Mr. and Mrs. Enoguanbhor Augustine for their assistance during my arrival in Germany, Mr. Vincent Onais, (Prince) Theophilus Okoro Akinyemi, (Prince) Victor Okoro Akinyemi, Esther Okoro Akinyemi, Osagie Okoro Akinyemi, Tuesday Okoro Akinyemi, Odion and Ovbokhan, Mr. Pulle Okoro Akinyemi, Mr. and Mrs. Ibrahim Obaretin, Christian Akonwe, and Mr. Nosa Edebiri, Managing Director of Distinguished Motors, Kassel, Germany. I am also thankful to the people of Edo Community Kassel e. V. Germany, African People Convention e. V., Kassel, Germany for their kind assistance and moral support. I convey my sincere appreciation to Ms. Alexandra Baltatu for her unflinching assistance and encouragement during the early stage of this tedious but rewarding work that has now been transformed into an elegant book. My warm appreciation also goes to Mr. Satty Smart Ariogun, Mr. Smart Ariogun, Mr. Lucky Ariogun, Mr. Stephen Awung, Mr. Joseph Mofor, Mr. Oghenevwaire Omo-Ojumah, Mr. Balogun Momodu and Mr. George Ugbo, and all the students of University of Kassel in Germany.

I wish to thank all authors, essayists and researchers whose works have contributed immensely towards making this book a success. My thanks and appreciation goes to Prof. Victor G. Stanley, Research Scientist, Prairie View A & M University, Texas, the United States of America, Prof. Christine Nicol, Bristol University, the United Kingdom, Dr. Frank T. Jones, Poultry Extensionist, Arkansas State University, the United States of America, Mr. Wieland Max, poultry farmer, Freudenta, Germany, Mr. Hans – Dieter, poultry farmer, Wustrow, Germany, and Mr. and Mrs. Kömpfer Marion and Marco, poultry farmers, Wustrow, Germany for providing me valuable suggestions and assistance during my Masters research in 2005.

I am grateful to Dr. S. Amini, Institute of Social Sciences, University of Kassel, Germany and Dr. Sahle Tesfai, Managing Director and Head of Department, International Centre North South Dialogue, Germany, for their valuable suggestions.

I also wish to acknowledge all the members of Ecological Agriculture Overseas Students Association (EAOSA) and my colleagues, University of Kassel, Germany, students and staff of Kotu Senior Secondary School, staff and students of Gambia Methodist Academy, The Gambia. My appreciation also goes to all the research institutions whose objective is geared towards improving agricultural development.

Above all, I wish to express my profound gratitude and appreciation to the Almighty God for providing me the inspiration, energy and encouragement to complete this work despite all odds.

Contents

<i>Foreword</i>	<i>vii</i>
<i>Preface</i>	<i>ix</i>
<i>Acknowledgement</i>	<i>xiii</i>
<i>List of Tables</i>	<i>xxi</i>
<i>List of Figures</i>	<i>xxiii</i>
<i>List of Graphs</i>	<i>xxx</i>

1. Introduction to Organic Agricultural Practices	1
1.1 Factors	2
1.2 The Ideal of Philosophers in Organic Agriculture Inputs	2
1.3 Organic Motivation	3
1.4 Necessity in Organic Farming	3
1.5 Certification Requirements	4
1.6 Trade in Organic Food	5
1.7 Marketing	5
2. Basic Concepts for Sustainable Agriculture and Rural Development	7
2.1 Key Challenges to Agricultural Systems	8
2.1.1 Eradicating Poverty and Hunger	8
2.1.2 Promoting Gender Equality and Women Empowerment	8
2.1.3 Achieving Environmental Sustainability	9
2.1.4 Promoting Human Health and Education	9
2.1.5 Water	10
2.1.6 Forestry	11
2.2 Agricultural Advancement	19
2.3 Enhancing Food Security	21
2.4 Agricultural Sustainability	22
2.4.1 Future Pace of Agricultural Production	23
2.4.2 Assessing Agricultural Sustainability	24

2.4.3	Sustainability of Food	25
2.4.4	Can Undernourishment be Strengthened in Africa?	26
2.5	Suggestions on How to Promote Agricultural Development	28
2.6	Factors Affecting Farmers	28
3.	Land	30
3.1	Land Tenure	30
3.2	Land Use	31
3.2.1	Types of Land Tenure Systems	31
3.2.2	Land Rights	32
3.2.3	Factors Affecting Land Availability	34
3.3	Rock Formation Processes	36
3.4	Soil and its Formation	38
3.4.1	Factors Affecting Soil Formation	39
3.5	Soil Composition and Property	42
3.6	Soil Organic Matter in Sustaining Soil Fertility	45
3.7	Soil Management Principles	46
3.7.1	Nutrient Enhancement	47
3.7.2	Tillage	47
3.7.3	Cover Crop Practices/Soil Structure Enhancement	48
3.7.4	Effects of Cover Crops in Rotation Scheme	49
3.7.5	Environmental Impacts of Cover Crops	50
3.7.6	Benefits of Cover Crops and Green Manures	50
3.7.7	Soil and Water Conservation	51
3.7.8	Soil Amendments	51
3.8	Soil Quality in Organic Systems	52
3.9	Organic Matter Content	53
3.10	Soil Biological Activities/Microorganisms	54
3.11	Soil pH	55
3.12	Availability of Nitrogen to Plants	56
3.12.1	Materials and Methods	57
3.12.2	Soil Sampling Technique	57
3.12.3	General Soil Properties	58
3.12.4	Soil Microbial Properties	58
3.12.5	Aerobic N-mineralization	59
3.12.6	Statistical Analysis	60
3.12.7	Results	60
3.12.8	Discussion	62
3.12.9	Conclusion	64

3.13	Factors Affecting Soil Fertility	65
3.14	Carbon Sequestration in Farming System	69
3.15	Organic Agriculture/Microclimates	69
3.16	Ground and Surface Water	69
4.	Effects and Consequences of Agricultural Chemicals on Soil	71
4.1	Consequences of Chemical Usage	72
4.2	Effects of Chemicals on Soil	73
4.3	Developing and Maintaining Fertile Soils	74
4.4	Preventing Outbreaks of Pests and Diseases	74
4.5	Implementing Changes in Chemical Applications	75
4.6	Ecological Strategies for Pest Control	75
5.	Pests and Diseases	79
5.1	Insect Pest Control	80
5.1.1	Classical Biological Control	80
5.1.2	Augmentative Biological Controls	81
5.1.3	Use of Crops	81
5.1.4	Conservation of Biological Controls	81
5.1.5	Beneficial Organisms	82
5.1.6	Parasitism	82
5.1.7	Predators	83
5.1.8	Lacewings	83
5.1.9	Lady Beetles	83
5.1.10	Damsel Bugs	84
5.1.11	Insects Attractants and Traps	84
5.1.12	Chemical Attractants	84
5.1.13	Pheromones	84
5.1.14	Allelochemicals	87
5.2	Control of Pests in Cotton Fields Using Alfalfa Plants	87
5.3	Induced Plant Disease Resistance	88
5.3.1	Forms of Induced Resistance	89
5.3.2	Mechanisms of Induced Resistance	89
5.4	Characteristics of Induced Resistance	92
5.4.1	Multiple Mechanisms	92
5.4.2	Lack of Specificity	93
5.4.3	Multiple Pathways	93
5.4.4	Interaction between Pathways	94

5.4.5	Mechanisms of Induced Resistance	94
5.4.6	Chemical Elicitors	95
5.4.7	GM Approaches to Plant Disease Resistance	95
5.4.8	Biological Elicitor	95
5.5	Discussion and Conclusion	96
6.	Weed Management	99
6.1	Beneficial Aspects of Weeds	100
6.2	Organic Weed Control	101
7.	Plant Nutrients and Nutrient Utilization	103
7.1	Major Elements	103
7.2	Micronutrients	109
7.3	Causes of Nutrient Loss and Solutions	111
8.	Mechanization of Agriculture	115
8.1	Agricultural Changes	116
8.2	Future Challenges for Machine Usage	117
8.3	Problems of Mechanization in West African Countries	118
9.	Plant Propagation	120
9.1	Introduction	120
9.2	Knowledge of Propagation	120
9.3	Seed Propagation	121
9.4	Vegetative Propagation	122
10.	Vegetable Production	123
10.1	Tomatoes	123
10.1.1	Soil Conditions	124
10.1.2	Fertilization	124
10.1.3	Transplanting	125
10.1.4	Spacing	125
10.1.5	Weed Control	125
10.1.6	Plastic Mulch	125
10.1.7	Staking and Pruning	125
10.1.8	Irrigation	126
10.1.9	Insect Control	126
10.1.10	Disease Control	126
10.1.11	Harvesting and Packaging	126
10.2	Carrots	127
10.2.1	Soil Conditions	127

10.2.2	Varieties	128
10.2.3	Seeding	128
10.2.4	Fertility	129
10.2.5	Irrigation	129
10.2.6	Harvesting	129
10.2.7	Storage	130
10.2.8	Problems of Production and Storage	130
10.3	Cultivation of Onions (<i>Allium cepa</i>)	133
10.3.1	Cultivars	134
10.3.2	Climatic and Soil Requirements	134
10.3.3	Planting Systems	135
10.3.4	Nutrient Management	135
10.3.5	Water Management	135
10.3.6	Weed and Disease Control	136
10.3.7	Post-planting Operations	138
10.4	Garden Egg Production	138
10.4.1	Cultural Practices	139
10.4.2	Climatic and Soil Requirements	140
10.4.3	Planting	141
10.4.4	Preplanting Operations	141
10.4.5	Harvesting Aubergine	142
11.	Developing Well Functioning Markets	144
11.1	Trend for Organic Markets	144
11.2	Foreign Trade with Organic Products	146
11.3	Prices of Organic Fruits and Vegetables	147
11.4	Supply Balance of Organic Vegetables in 2001	148
11.5	Consumer Habits and Product Preferences	149
11.6	General Discussion on Organic Markets	150
11.7	Recommendation	151
12.	Livestock Production	153
12.1	Poultry Production	153
12.1.1	Practical Poultry Production	155
12.1.2	Role of Water in Chicken Development	166
12.1.3	Incubation	167
12.1.4	Relative Humidity Control	169
12.1.5	Air Movement	169
12.1.6	Brooding Hen	170

12.1.7	Temperature Control in Poultry House	171
12.1.8	Culling Laying Hens	172
12.2	Management System	172
12.2.1	Pastured Poultry (Extensive System)	173
12.2.2	Range Production	175
12.2.3	Semi-intensive System	176
12.2.4	Intensive System	177
12.2.5	Effects of Environment on Production	179
12.2.6	Heat Stress in Broilers	181
12.2.7	Environmental Design and Animal Well-being	182
12.2.8	Housing Environment and Disease Prevention	184
12.2.9	Health Management	185
12.3	Cattle Production	188
12.3.1	Environmental Condition	189
12.3.2	Ecological Settings for Dwarf Muturu	189
12.3.3	Management and Production Systems	191
	References	197
	Index	221

List of Tables

1: Particle sizes based on USDA and International Classification Systems	42
2: Effects of: (1) soil management practices, and (2) fields, on the measured soil characteristics (NSD = no significant difference)	60
3: Comparison of results of microbial biomass and activity, with that of literature	62
4: Phosphorus and potassium balances (kg/ha) compared with organic and conventional farms	77
5: Direct and indirect weed control	102
6: Recommended legumes for organic sources	105
7: Harvesting and packaging	126
8: UK retail prices for organic fruits and vegetable in pounds (£) and euro (€) in January 2001	145
9: Price premium for some organic fruits and vegetables in Germany (2001) imported from the countries listed below	148
10: Average price at retail level and premiums for the stated organic products	148
11: Supply balance of organic fruits (2001)	149
12: Body weights and feed requirements of broilers	162
13: Nutrient requirements of leghorn-type chickens as percentages or units per kilogram of diet	163
14: Nutrient requirement for leghorn	163
15: Nutrient requirements of broilers as percentages or as units per kilogram of diet	164
16: Recommended daily nutrients for laying hens	165
17: Nutrient formulation for young chicks	165

List of Figures

1: Factors affecting soil formation	39
2: Soil composition	42
3: Picture showing a particular cover crop (Echinacea)	49
4: Nitrogen Fixation	57
5: Effect of (1) soil management practices and (2) fields on pH of soil	61
6: Effect of (1) soil management practices, and (2) fields on N-mineralization in soil	61
7: Systemic induced resistance	97
8: Signal transduction pathway for SAR and ISR in <i>Arabidopsis thaliana</i>	98
9: Mechanisms of systemic induced resistance showing production and accumulation of enzymes, PR proteins, HR and signal transduction	98
10: Combine harvester	117
11: Harvester	118
12: Structure of flowers	121
13 and 14: Number of plutella (DBM) and percentage parasitism on cabbage of substance farmers at Graliams-town 2000/2001.	133
15: Poultry house with sitting places	174
16: Free range system	175

List of Graphs

1: Relationship between water consumption of laying and non-laying hens	167
2: Temperature rate for incubation	168
3: Temperatures and relative humidity measurement required for a laying hen	170
4: Brooding temperature in degree Celsius and in Fahrenheit	171

Introduction to Organic Agricultural Practices

1

Chapter

Organic agriculture by definition is referred to as a “natural production management system which promotes and enhances biodiversity, soil biological activities and biological cycles.” The production is based on minimal use of off-farm inputs and good management practices that restore, maintain, or enhance ecological harmony. The main goal of organic agriculture is to optimize productivity of interdependent communities of soil life, plants, animals and people with the use of synthetic elements. The term “organic”, as defined by law, is “natural” and “eco-friendly”. Most “natural” products do not contain synthetic products, but may have been produced conventionally (using synthetic substances).

From ancient times, organic agriculture is regarded as the most traditional form of agricultural management system in the universe. Farming without usage of petroleum-based chemicals (fertilizers and pesticides) was the sole option for farmers until the World War II. The war brought with it technologies that were useful for agricultural production (the use of ammonium nitrate fertilizer). The *organophosphate nerve gas production* at this stage led to the development of powerful insecticides that were used in the eradication of insects after the end of the World War II. The significant economic benefits of agriculture, as well as the environmental and social detriments, resulted in the advancement of this technique.

Organic agriculture, therefore, seeks to utilize advances that consistently yield benefits (new varieties of crops; crop rotation, mulching, technologies; more efficient machinery) during these periods, and has discarded the methods that lead to negative impacts on society and environment.

Due to the adverse effects of using synthetic fertilizers and pesticides, *organic farmers prefer utilizing crop rotations, cover crops, and natural-based products to maintain and enhance soil fertility*. Currently, farmers rely on biological, cultural and physical methods to limit pest expansion and

increase populations of beneficial insects on their farms. Genetically modified organisms (GMOs) constitute synthetic inputs and pose unknown risks to both crops and animal production. Presently, GMOs such as herbicide-resistant seeds, plants, and product ingredients, like GM-lecithin, are disallowed in organic agriculture.

1.1 FACTORS

Organic Products Consumption

Several statistical analyses have proved that worldwide consumption of organic products has experienced a significant growth over the years, and most of the increase in global consumption has been fueled by consumers' demand for GMO-free products. As a result of banning GMOs in organic production and processing, the crops and livestock have been classified as GMO-free at the marketplaces. This has evinced keen interest by consumers in organic production. In Europe (Netherlands and Scandinavia) and other parts of the world, consumers are demanding organic products because of their naturalness. Numerous publications have shown that 2% of total German farmland, 4% of Italian farmland, 10% of Austrian farmland, respectively is managed organically. Though, the higher demand for organic consumption in Europe is Germany. Prince Charles of Great Britain has also developed a model of an organic farm, and established a system of government support for transitional organic farmers. Major supermarket chains and restaurants in Europe offer a wide variety of organic products for sale in the market, and on their menus (Delate, 2005) to combat competition.

1.2 THE IDEAL OF PHILOSOPHERS IN ORGANIC AGRICULTURE INPUTS

The basic purpose of using natural elements in organic agriculture is attributed to the protection of environment, concern for the economy and food safety. Organic producers differ in their methods adapted to achieve the idea systems. Some organic farmers entirely neglect external inputs and concentrate on native biological insect controls on their farms by conserving beneficial insects' food and nesting sites, instead of importing natural pesticides. They create compost on the farms for fertilization needs. Others do not make a distinction in inputs, and rely on imported inputs for soil fertility and pest management. Organic farming seeks to eliminate any chemical substance not in compliance with the rules and regulations of organic farming practices. They rely mainly on products produced on farms.

1.3 ORGANIC MOTIVATION

The motivation for organic production is based on economic consideration, food safety and environmental concerns. It is essential that all organic farmers avoid the use of synthetic chemicals in their farming systems if they are expected to sell their product as “organic”. Philosophers among organic farmers regard organic farming as the best method of producing crops and animals, and as the most ideal management method in farming systems. Organic farmers span the spectrum from those who completely eschew external inputs and create on-farm sources of compost for fertilization and encourage the activity of beneficial insects through conservation of food and nesting sites, for farmers who import their fertility and pest management inputs. The philosophy of “input substitution” is discredited by many long-time advocates of organic agriculture. A truly sustainable method of organic farming would be to seek elimination, as far as possible, of external inputs (Delate, 2005).

1.4 NECESSITY IN ORGANIC FARMING

Organic products must be certified as “organic”, so as to ensure farmers do not use substances prohibited according to organic regulations. Farmers growing organic crops and raising organic animals must follow a set of prescribed practices that include avoidance of synthetic chemicals in crops and livestock production, and in the manufacture of processed products. Organic certification agencies have been established in different parts of the world to educate farmers and to deal with required elements needed in organic production. The certification bodies range from state to third party certification agencies. Some of the certification bodies in Europe include AMAB, IMC, Diameter, Bioland, Codex Alimentarius, Associazione per Bioagricoop and Associazione per l'Agricoltura Biodinamica (AIAB). The International Federation for Organic Movement (IFOAM) is also a certification body representing and certifying organic products worldwide. States or countries have the right to set up well-defined organic standards to suit organic production, but the standards must meet the international guidelines so that the organic produce can be exported to other countries where they are in demand. The standards set by states must specifically spell out penalties for producers falsely identifying their products as “organic”. The law must also allow private certification bodies to operate. More information on organic agriculture and organizations can be found on the homepage <http://www.organic-europe.net/>.

The rules set by states or countries should include a clause, whereby all farmers, whose gross income from organic sales is more than US\$ 5,000 per

year, in conversion to the country's currency, must be certified as "organic farmers" through an accredited agency. The small scale producers are allowed to receive the benefits of premium prices (provided produce is raised organically) while avoiding certification fees. However, farmers are encouraged to join a certifying association in order to participate in the benefits of sharing information among members.

1.5 CERTIFICATION REQUIREMENTS

To sell a product as "organic", it must be raised on land free from synthetic chemicals (any fertilizers, herbicides, insecticides or fungicides) and inputs. No GMOs should be allowed in the raising of crops and livestock. According to the regulatory system, conventional and organic fields can be located on the same farm, but special care, including a border of 30 m between organic and conventional fields is necessary in mixed operations. Only naturally-occurring materials are allowed in production and processing operations and all treatments must be noted in the farm records.

Diverse crop rotation plan is extremely essential as it protects crops against pests and supports the recycling of soil nutrients, thereby keeping the soil biologically active and rich in organic matter. The rotation should not be practised for more than four out of six years and the crops should be in rows. The same row crop must not be grown in consecutive years on the same land. Legumes such as alfalfa, red clover, berseem clover, and hairy vetch, alone or in combination with small grains like wheat, oats, or barley are recommended to be rotated with row crops like corn, soybeans, amaranth, and vegetables, so as to ensure a healthy system. It is also recommended that horticultural crops be rotated with leguminous cover crops at least once every five years. Other practices are specifically disallowed in organic production in most regulations. The use of "biosolids" or sewage sludge is not encouraged as it may result in undesirable bacteria and heavy metal contamination. Farmers should be made aware that irradiated products are prohibited because of the harmful elements that occur in irradiated substances. They should also be well versed with products used in organic cropping systems and animal production, in order to be fully classified as "organic" producers.

Like other livestock, organic livestock, must be fed with 100% organic food or feed in their production unit. Synthetic hormones and antibiotics are strictly discouraged in organic livestock production. However, the natural bacteria present in vaccinations are permissible in organic livestock production and instead, synthetic parasiticides are prohibited. Organic farmers should rely on natural parasiticides like diatomaceous earth.

Purchasing parasite-free stock, and providing access to ample pasture, water, and nutritional feed should be allowed for healthy organic livestock production (Delate, 2005). It is highly recommended for livestock to be provided with access to pasture in order to be certified “organic”. Alternative health therapies such as botanical remedies and manipulation technologies should be used by organic livestock producers.

1.6 TRADE IN ORGANIC FOOD

Trade in organic food differs from other food commodity networks because of the need for organic certification. Certification of organic produce within the European Union, whether produced domestically or imported, is regulated by Regulation (EEC) 2092/91 (Barrett et al., 2002). This regulation came into force in 1991 with the aim of protecting consumers, and harmonizing producers with the definition of ‘organic’ production among EU member states. This provides the legal framework for accrediting private sector certification bodies (Willer and Yussefi, 2001).

It is mandatory for organic certification bodies to fulfil the requirements of the European Norm 45011. This norm was incorporated as an amendment to the EU organic legislation, and specifies requirements for third-party organizations who operate certification systems (Marian and Felipe, 2004).

Exports of organic products from third countries into the EU market, as indicated under Article 11 of EU regulation 2092/91, have to meet two options (Barret et al., 2002). Firstly, the exporting country should be recognized as having equivalent standards to the EU regulations with regard to agricultural production, processing, documentation and inspection. Secondly, if approval is granted, the country will be added to the List of Third Countries (Marian and Felipe, 2004). Currently, there are only seven countries recognized under Regulation (EEC) 2092/91 Article 11(1) Annex (EEC) 94/92: Argentina, Australia, Czech Republic, Hungary, Israel, Switzerland and New Zealand (Barret et al., 2002).

1.7 MARKETING

Over the last ten years, there has been increased awareness in organic food produce and its marketing by mainstream retailers (Barrett et al., 2002). As a consequence of the recent food safety, consumers are enquiring about the methods used in producing organic food and marketing, which has resulted in increased worldwide demand for organic products. In Europe, the trade of organic products has significantly increased in the recent years (Marian and Felipe, 2004). Barrett et al. (2002), states that the global market for

organic products is estimated at US\$ 11 billion, the equivalent of 2% of the total world food market. Organic imports from developing countries are worth about US\$ 500 million (according to IIED, 1997; Blowfield, 1999; Robins et al., 2000). Europe is the leading and largest world organic market with an estimated share of US\$ 5 billion in 1997 (Willer and Yussefi, 2000). Currently, the most important organic products within the EU market are vegetables, fruits, potatoes, milk products and cereals (Michelson et al., 1999).

Supermarkets in the UK, for example, are currently boosting the range of organic products in their stores and investing heavily in advertising and promotion of organic food (Barrett et al., 2002). Presently, sale of 70% of all organic fruits and vegetables are routed through supermarkets (FAO, ITC and CTA, 2001). It is extremely necessary for organic producers in developing countries to increase their produce, keeping in view the long-term environmental benefits of organic farming.

Basic Concepts for Sustainable Agriculture and Rural Development

2

Chapter

The World Commission on Environment and Development under the United Nations has drawn attention to the challenge of population growth over the years, which is currently affecting food availability for world consumption. The conclusion of the world summit on sustainable development held in Johannesburg in South Africa in 2002, recommended that strategies should be formulated for sustainable food security and environmental conservation of natural resources, so as to meet the food requirements of the present and future population growth. In an attempt to mitigate the constraints currently faced by producers and consumers, the following plan of action was put forward:

- ❖ Plan of action should be implemented for sustainable development.
- ❖ There should be adjustments in agricultural production, environmental management and macroeconomic policy at both national and international levels.
- ❖ There should be a necessity to create conditions for sustainable agriculture and rural development.

The major focus of sustainable agriculture and the promotion of rural development should be to increase food production in a sustainable manner with the intention of enhancing food security and environmental protection. The attainment of this act will involve educational initiatives, utilization of economic incentives and development of appropriate and new technologies, thus ensuring stable supplies of adequate food, having access to those vulnerable groups to whom the products were supplied for marketing, and income generation for the rural people to alleviate poverty.

Sustainable agriculture is generally associated with the need for agricultural practices to be economically viable to meet human requirements, to be environmentally positive, and to improve the quality of life. The objective of sustainability can be met in a number of ways. Sustainable agriculture is not affiliated to any particular technological

practice, but is the exclusive domain of organic farming. The salient features of sustainable agriculture are its adaptability and flexibility over a period of time to respond to the demands for food and fibre. Sustainability helps to protect soil quality and improve food availability.

2.1 KEY CHALLENGES TO AGRICULTURAL SYSTEMS

Agriculture can make significant contributions towards attaining maximum advancement of a country when given more attention. It is through the agricultural sector that most of the rural poor in developing countries derive their income and daily meals. As organic agriculture depends heavily on natural resources, its influence contributes to environmental sustainability. However, to attain the best results from farming, producers should understand the following key challenges:

2.1.1 Eradicating Poverty and Hunger

The best way in which the international development community has tried to engage with the politics of achieving poverty reduction over the past decade has been through the notions of good governance and social capital (World Bank, 2001). Good governance is associated with the accountability and responsiveness of political systems, to be achieved through reforms such as democratic decentralization. To achieve this aim, agriculture should not be neglected, as food production is essential for consumption, export and income generation to boost the country's economy.

It was estimated by the United Nations that the world population living on less than US\$ 1 per day is 1.2 billion people. It was additionally supported that the world population living on less than US\$ 2 per day is about 70%. Currently, about 800 million people worldwide go hungry each day out of which approximately 75% of the poor people are from developing countries and most of them live in rural areas, where they depend mostly on agriculture for their livelihood. The reduction of poverty and hunger in both rural and urban areas will depend on sustainable development of agriculture. To achieve these goals, there must be promotion of pro-poor economic growth in proportion to the population growth rates. This will require raising agricultural productivity, integrating agriculture into local and international markets and creating productive on- and off-farm employment for the rural dwellers.

2.1.2 Promoting Gender Equality and Women Empowerment

Several researches have drawn the attention of the world to the fact that women are responsible for half of the world's food production. It was

estimated that female workers contribute between 60–80% of the food produced in developing countries. Women predominantly occupy the labour forces. Their specialized knowledge on genetic resources also makes them essential custodians of biodiversity for food and agriculture.

However, women's fundamental contribution is continually under-appreciated and under-supported, and is often adversely affected by prevailing economic policies and other developmental conditions. These circumstances must be reversed, as sustainable rural development through agriculture cannot be achieved without the full participation of women.

2.1.3 Achieving Environmental Sustainability

The natural resource base of suitable land, water, forests, and biodiversity largely determines the potential of agriculture. These resource endowments have a major influence on human activities in agriculture. Historically, agriculture was believed to respond only to the need of man for food, but it was later understood to respond to poverty reduction. Now it seeks to simultaneously meet the triple objectives of poverty reduction, food security, and environmental sustainability.

Most of the land suitable for agriculture is already being used as farmlands. Therefore, meeting current and future food requirements will need rapid increase in productivity; otherwise, it will result in an undesirable expansion onto fragile and marginal lands. There is widespread concern that deforestation and land degradation are severely diminishing the potential of ecosystems. The main causes of these conditions go well beyond agriculture; agriculture does play a role when policies are inappropriate, unsustainable agricultural practices are used and property rights are insecure.

Biodiversity supports the production of an ecosystem's goods and services essential for life as well as many cultural values. Improving crops, livestock and feeds; soil fertility; and controlling pests and diseases often depend on these resources; however, increasing population pressure, deforestation, and unsustainable agricultural practices are contributing to degradation of these "life insurance policies."

2.1.4 Promoting Human Health and Education

Good health and education are two prerequisites for sustainable development, and agriculture contributes to these aspects both in positive and negative forms.

Adequate nutrition is indispensable for attaining good health. An adequate supply of food is a key determinant of adequate nutrition. This

factor alone can drastically reduce malnutrition in adults and children, and increases the birth weight of newborn babies. Improving incomes, nutrition and provision of seeds for agricultural productivity can help prevent the cycle of passing malnutrition from one generation to another. Savings from agriculture provide means of education for farmers' children.

Agricultural practices, no doubt, may have a negative correlation on human health and education. For example, overexposing adults and children to dangerous chemicals and harmful forms of farm implements and tools may affect child labour in both the family and commercial scenario. In addition to exposure to dangerous chemicals, children may suffer long working hours, lack of access to education, very low or no pay, and injury due to heavy loads and dangerous machinery, as previously mentioned. If children must work to support themselves, they should be assisted not only with programmes that reduce the physical risks they face, but also with leisure time, flexible schooling, and attractive payment.

2.1.5 Water

Water is an indispensable resource for agriculture and has played a pivotal role in the development of this sector. It is also scarce and unevenly distributed both regionally and among certain marginalized populations, especially in developing countries. Agriculture is the largest user of water, accounting for about 70–75% of the total freshwater withdrawal globally, and between 85–95% in developing countries. Currently, water used for agriculture may not be sustainable because of both scarcity and competition for use by other sectors such as human consumption, health, sanitation, and various industries. As a result, many innovations to improve water use efficiency are being tried, and others such as more water efficient crops are also needed.

Water, by definition, is very vital for all living organisms. In plants, it serves as a mineral dissolvent and a medium for nutrients absorption. It helps in nutrients transportation, regulates plant and soil temperature, keeps plant cells turgid and gives them their natural shape and support. It also plays a great role in plants food synthesis. As a result, large quantities of water are needed to satisfy plant requirements.

Soil water is classified into three major types according to (Akinsanmi, 1994). Water may appear in the form of gravity (**gravitational water**) which is held at field capacity level. It is usually stored in the macro pores. This type of water *affects plant growth and causes poor aeration that restricts roots and soil organisms of oxygen (O₂)*. Its movement is in the form of gravity and may cause the leaching of soil nutrients. **Capillary water** is stored in medium pores and

found between capacity and hydroscopic or the wilting points. It usually follows a flow movement from higher concentrated regions to lower concentrated regions. **Hydroscopic water** is usually at the equilibrium level. It is found in hydroscopic coefficient. It is not a liquid, but usually moves in the form of vapour.

It is recognized that the absorption of water occurs in the form of osmosis which involves the movement from higher regions to lower region concentration. It is recommended that further research be conducted to investigate if there is any other form in which water is absorbed by plants.

2.1.6 Forestry

Forests have historically provided shelter, food, fuel, medicines, and building materials for both man and animals. More recently, forests have become sources for new goods and services such as pharmaceuticals, raw materials, recreation, and carbon sequestration. However, forests now cover only 24% of the world's land surface and a net loss occur in developing countries. There are no simple answers to deforestation, but developing sustainable agricultural systems will help ensure that forests continue to provide both traditional and new goods and services.

Forestry, by its nature and location, is rurally based and conservative (Asmal, 1995). It is defined as the study and management of forests and their resources. Forest industries that are spawned have become successful, powerful and dominant. Forests supply a country's needs. The products obtained from forest such as wood is used for clothing and book manufacturing. Wood products are major export items for some countries in Africa, as they generate foreign exchange and to boost the country's economy.

The policy on the future of forestry must continue, not only to foster and encourage industries that play a vital role in a country's economy but also to ensure that forestry, hitherto almost reclusive, is brought to people in a manner so as to enhance their quality of life as a result of reconstruction and development programmes.

The policy on forestry should be based on the common vision of achieving national benefits. Laws should be enforced on forest exploitation in order to avoid misuse of the resources. Laws can help bring harmony in the relationships between the different elements that lay claims to forestland and scarce water resources, and bring equity into forest allocation. Forest laws help preserve flora and fauna and the natural environments as people are prohibited from harvesting from certain forests.

Environmental concerns regarding forestry emerged from the mid-18th century in South Africa. This was focused on the ecological and hydrological

effects of fire hazards, and the need to conserve forests for a greater influence of their products have become imperative, especially as a source of income for a country.

Controversy about the effects of afforestation on water supplies started in the early 1920s, and it still remains unresolved. This has resulted in great control on afforestation that has been applied over the years in most African countries. From analyses and results of demonstrations, only a small percentage of land is afforested in Africa. This has led to an intense controversy about the broader environmental impacts of forestland, and not just the effect on water alone.

In a nutshell, a new forest policy must be addressed by the people in African countries, in order to meet its benefits and demands and generate foreign exchange earnings.

(a) Fundamental Challenges to African Forests

In a research conducted on African forests, it was observed that there is a lot of negligence in the proper management practices of forest products and their resources. The inappropriate management, however, may continue to pose a serious catastrophe to its expansion if a change is not implemented. It is imperative to find a solution that would resolve these problems in order to promote sustainable forest resources. Recognizing the role of forests in economic development, conservation of biological resources, and maintenance of natural systems is highly imperative. Governments, private sectors and citizens should be aware of the importance of forests and their resources. Citizens and individuals should be acquainted with the fundamental challenges faced by countries and meaningful recommendations should be implemental with a view to ratifying the problems for further advancement. In most countries, there are three basic challenges faced. The challenges include:

- ❖ Prevention of wasteful deforestation and forest degradation of tropical dry forests through: (a) correction of distorted policies; and (b) conservation and sustainable use.
- ❖ Revitalization of the wood industry to enhance efficiency and competitiveness.
- ❖ Augmentation of the resource base through tree planting and regeneration.

(b) Forest Zones in Africa

Forest vegetation is usually found in areas where there is abundant rainfall and the humidity at 8–9 am ranges between 70–80%. Forest zones are basically divided into four major parts in West Africa. The zones include fresh water swamp, mangrove swamp, rain forest and savannah.

1. Fresh Water Swamp

The fresh water swamp is mainly found behind mangrove swamps. The annual rainfall ranges from 2,500 to approximately 3,000 mm. The land may be seasonally flooded by rivers when the temperature rises above 12°C. The relative humidity range is between 70–75% at 9 am.

2. Mangrove Swamp

The mangrove swamp receives more rain than the inland areas. In West Africa, the coast of Guinea, Sierra Leone, Nigeria and Liberia are usually under the influence of southwest trade winds. The average rainfall in these regions is over 3,000 mm. The yearly temperature is just 3°C. However, Akinsanmi (1994) pointed out that the daily temperature range is usually higher than the annual temperature range. The relative temperature is high and helps in protecting excessive evapo-transpiration. Short, red and white mangroves trees with prop roots and raffia palm are found in this zone. The animals found in this area include crocodiles, birds, fish, snakes and rodents.

3. Rain Forest

This zone stretches through Ghana, Sierra Leone, and Nigeria in the southeastern border upto the Cameroon Mountain. The animals found here include monkeys, grass cutters, snails, antelopes, deers, porcupines and warthogs. The plants include rubber, kola nut trees, palm trees, cocoa, and timber such as obeche (*triplochiton scleroxlon*), ebony (*Diospyros* spp), teak (*tectonagrandis*), iroko (*chlorophora*) and mahogany (*khaya grandifolia*)

4. Savannah Zone

This zone can be divided into Guinea savannah, Sudan savannah and Sahel savannah. The Guinea savannah occupies a large area in West Africa. It stretches from southern Senegal, covering 75% of the total area from Guinea to Ghana, with the centre located in Nigeria. Its vegetation is identified by tall grasses and short trees. Its annual rainfall ranges from 1,500 mm in the south and about 1,000 mm in the north (Akinsanmi, 1994). The area has about four to six months of dry season and six to eight months of rain.

The Sudan savannah is found in the northern part of the Guinea savannah. It spans from West Africa through Senegal, to northern Nigeria. It has an annual rainfall of about 600 mm spread over a period of three to four months. The relative humidity is usually low while the temperature is high. The vegetation contains seasonal short grasses and wild fruits like baobab,

scientifically known as “*Adansonia*”. This plant is common in The Gambia, Senegal, Mali and Guinea.

The Sahel savannah is found in the northern part of the Sudan savannah. Its rainfall is only for a period of one to two months throughout the year. The vegetation consists of sparse thorny trees, acacia, data palms, neem trees, millet and short grasses.

(c) Policies on Forest Conservation

A policy is a statement of intents or objectives that government sets out as part of its overall vision. It provides a framework that guides and determines the action of government. A policy is set to show what is to be done in particular situation that has been agreed officially by a group of people (Asmal, 1995).

Policies have been formulated on forests in African countries, but as yet a well-documented and defined programme has not been implemented to check the mismanagement of forestland. With a view to implementing a well-defined policy, some of the following prominent aspects of current forest plans have been put forward in this book, based on research results of other publications:

- Devolved management of wilderness areas and other extensive conservation areas on state forests under the responsibility of Provinces should be implemented.
- Responsibility for management, or oversight of management, of natural forests in a country retained by the Department of Water Affairs and Forestry should be re-visited.
- Annual national inventory of commercial plantation forest resources and wood-processing industries should be well-documented.
- National self-sufficiency in wood for commercial purposes should be looked into.
- Incentives should be offered for afforestation.
- Control of afforestation in favour of water resources, with provision for other environmental impacts through environmental impact assessment where necessary, should be focused on.
- Social forestry responsibility for government, pursued through a nursery and a woodlot programme in Department of Water Affairs and Forestry and the Biomass Initiative of the Department of Mineral Resources and Energy Affairs, should be implemented.
- Recognition of self-regulation by companies and farmers with respect to environmental management and sustainability should be emphasized.

- All elements of the policy should be tested against a set of principles that would allow the determination of the appropriate policy.

(d) Reforming Forest Laws

Several factors determine the need for a new Forest Act. These include:

- the need for a democratically-based law,
- existence of certain incongruencies in the present Act, and
- the need to incorporate relevant provisions arising from international laws and customs.

(e) Scope of Forest Laws and Policy

In many African countries, the existing policy on environment encourages inappropriate forest use by undervaluing and underpricing forest resources. To rectify this situation, it is essential to make markets for forest products work better and more effectively for producers, and to take account of non-marketed benefits in decisions on forest utilization. Failure to comply with this policy will result in disaster. It is, however, recommended that the issue affecting these factors be addressed through a process of dialogue among various stakeholders.

Forest laws and policy reflect an integrated approach to protection, management, and use of forest resources of any kind. This approach has the advantage that forest resources are specifically identified on the national agenda, with clear responsibilities in accordance with the international customs and "soft" law (Asmal, 1995).

The alternative is to separate the portfolio of resource conservation from the portfolio of resource exploitation and the conservation provisions of Forest Act. Through forest laws, industries could operate independently within the framework, and simultaneously be controlled by environmental legislations. This will help check the conflict of interest currently posing problems to forestry.

(f) Forest Development

Plantation of important trees should be encouraged in diverse vegetation through regeneration, reforestation and afforestation. To have a precise and appropriate forest development, the following have a great role to play:

• Farmers and Community Involvement

Through policy and legal change, training in participatory planning will enable forest agencies to develop a partnership in forest management and reforestation with local communities and NGOs. Government support for participatory negotiation processes involving forest users will facilitate

sustainable forest management by local people and eradicate conflicts among community members.

- **Private Sector Involvement**

Governments should shift their role from direct involvement in production towards providing a policy and legal environment, and information services that would stimulate the interest of private investment in forests as a means to provide more efficient wood industry. The involvement of private sectors on policy making will, no doubt, promote efficient management of forests.

- **Improving Knowledge and Technology of Forest Production**

The need to conduct forest inventories in any country will serve as a basic tool for planning, monitoring, implementing and evaluating forest activities. Information gathered from the field should be disseminated in a wide array for the benefit of the public. Due to the importance of forest, the need for a comprehensive research geared towards forest improvement and development will serve as the basic catalyst for sustainability.

- **The Role of Investors in Forest Development**

The role of investors in future forest development is to ensure that four key factors are met. The key areas identified are:

- Promoting policy reforms
- Supporting capacity building and human resources development
- Supporting investments in critical areas
- Promoting better donor coordination in the forest sector through investment

In order to obtain maximum developmental impact, forest sector operations should be part of an integrated long-term programme. Long-term programme approach would embrace a broad range of lending instruments for improving forest sectors including structural and sectoral adjustment loans that may be given by the World Bank or other interested organizations.

- **Conservation of Forests and their Resources**

- Conservation of forests should be protected irrespective of their ownership.
- State forests should be privatized.
- Nature reserves, wilderness areas and national parks, in terms of the Forest Act and other statutes, would need to be properly recognized, and the role of a new forest act with regard to these lands must be clarified.
- Recognition of the rights of local communities is imperative.

- Provide a comprehensive overview and analysis of the forest sector.
- Map out a corresponding set of actions for consideration.
- **Sustainable Forest Management**
 - Protection of water resources and soil, conservation of biodiversity and cultural heritage.
 - Forest management within protected forests should be described as multiple functions and sustainable use of forest lands.
 - Public access to forests for recreation, grazing of animals, collection of wood and other forest products should be treated at par with the provisions for joint or participatory forest management.
- **Control of Afforestation**
 - Providing guidelines and regulations for the protection of water resources and nature.
 - Planting new trees by the Department of Agriculture and Forestry.
- **Forest Protection**
 - Providing protection against fire hazards, management of pests and diseases, consistent with the provisions of plant protection legislation.
- (g) **Government's Role and Support Institutions**
 - Recognition of delegation to local government, community-based organizations, and others.
 - Forest research and training programmes should be included in: (1) the Act, (2) school curriculum for students' awareness on forest management and government, and (3) legislation.
 - Forest inventories, forest statistics and other monitoring of forest resources.
 - Incentives like tax exemptions, grants and soft loans to support afforestation for conservation and recreation, to support public access and recreation facilities, restoration of degraded lands, and related matters.
 - Financing of administration, grants, loan interests, research and training may be included through tariffs and charges.

(h) **Uses of Forests and their Products**

Forests are used by a number of user and interest groups, each extracting specific products. Long-term security of forest resources depends on the activities of stakeholders. However, the continuous degradation and depletion of forests is still very rampant in Africa, yet the concerned authorities have not been successful in stopping this act. With the depletion of communal forests and increasing pressure on the remaining state-owned

forests, a better arrangement has to be made to guarantee the future of existing forests (Joseph and Ngwasiri, 1995).

Forest products can be classified in terms of proximity to the forest resource. The classification of forest is based on the national population and the international community. Forests and their products can be used in the following varied ways:

- ❖ **Productive uses:** Products including timber, bark, vegetables, fruits, medicinal plants and wildlife. These products can be exported for earning foreign exchange.
- ❖ **Aesthetic uses:** They can be used for tourism attraction, which in turn generates foreign exchange and rural development.
- ❖ **Protective uses:** They serve as a means of environmental protection, steep slopes, biodiversity, etc. This is the primary concern for the international community.
- ❖ **Conservation:** They play a great role in agricultural production. The roles include increasing of rainfall the amount of, soil fertility, nutrient turnover and replacing lost nutrients from the soil.
- ❖ **Employment and income:** Forest provides employment for certain group of people called forest guards. These people are recruited or employed by the Ministry of Forestry with the intention to secure forest and its resources. In addition, forest provides income for hunters as they sell the animals hunted in the forest. On the other hand, hunting of animals do not promote agricultural production as it affects the biodiversity. It is recommended that forest should be protected as hunting and destruction of forest may affect our environment. Moreover, preventing forest exploitation is a way of beautifying our environment and increasing the amount of rainfall.

(i) Types of Forests

• State-owned Forests

State-owned forests are exclusively preserved for the purpose of future development. In some countries, these types of forests are only the relic forests available. However, in the face of increasing population and economic recession, these types of forests are controlled under mounting pressure by the State Ministry of Agriculture as increase population requires some of the forest product.

States should draw up work plans for forests and follow up the operations such as silvicultural activities, harvesting, law enforcement, revenue collection, granting concessions, etc. Local people may enjoy some customary rights, but if they frequently inhabit the forests, they are considered as encroachers (Joseph, 1995).

It is becoming obvious to many governmental organizations responsible for state-owned forests that they can no longer successfully implement the management practices of forests without involving the people staying in the surrounding area, whose livelihood is forest-based. In addition, democratization and current multi-party politics in many countries have resulted in government authorities being deprived of the power to stop the act of involving people in managing forests. Governments are advised to look into this issue critically.

- **Communal Forests**

A community controls communal forests as they stand on communal lands. These forests are usually freer for all, bringing revenue to the people directly, as they extract and use or sell the products. These forests are rare and have fewer restrictions than state-owned or private forests. The communities have greater freedom of access to these types of forests as they belong to the entire community in a specific location. Communal forests are prone to a higher degree of degradation than the forests under management regimes, as they are usually exploited by the local people, who use the land and forest resources as they consider suitable.

- **Private Forests**

Private forests belong to individual people who may do whatever they wish to the land, as it is their personal property. However, in some cases they are legally bound to comply with certain regulations guiding the state or community. Occasionally, government agents check whether the activities being carried out by the individual owners are lawful, and not detrimental to the public interest. This restriction helps in proper management and promotion of biodiversity.

2.2 AGRICULTURAL ADVANCEMENT

The challenges in agricultural production are faced mainly by five basic principles. Without the understanding of these principles, agricultural development will be continually on the decline.

The challenges include:

- (i) **Creating New Options for the Poor**

Agricultural productivity, which is currently low, must be steeply increased. Appropriate technologies and sustainable production techniques can do much to meet this challenge. As agricultural productivity rises, it will almost inevitably displace farm labour. Therefore, more opportunities must be created for off-farm employment. Agro-based processing is one route that can

add value to primary agricultural products and help reduce unacceptable high post-harvest losses.

Three requirements must be met to create these new opportunities for the rural poor:

- Avoid destabilizing local prices
- Market access must be facilitated
- Concerted long-term efforts must be made to achieve the principal objectives

(ii) Empowering Developing Countries

Sustainable agricultural development requires strong institutions (both public and private) and an appropriate enabling environment. Developing countries are also required to expediently respond to agriculture and other global governance mechanisms related to trade, environment, genetic resources, and others. Many countries have little capacity to do so. Successful developmental efforts will increasingly depend on implementation of the appropriate policies and institutional capacity to manage the complex rural environment in which agriculture must develop.

(iii) Building and Sharing Knowledge

Over the years, it has been predicted that agricultural growth would fail to meet the food needs of growing populations, leading to starvation and death on a global scale. Those predictions were averted because of rapid progress in technology and use of information. Even with such progress, poverty is widespread among rural people. Reduction in agriculture in developing countries has led millions of people to die of hunger and famine. Overcoming these challenges is made progressively more difficult by rapid population growth on the fixed natural resource base. Agricultural innovation, therefore, must clearly continue at an accelerated rate in order to respond to these challenges. Unfortunately, investments in research suffered most during the past decade of low investments in agriculture. There is an increasing fear that creation of the requisite new knowledge and agricultural techniques of particular interest to developing countries is lagging. Without the ratification of these problems, food shortage will continue to increase.

(iv) Relying on Partnerships

Creating opportunities to allow the poor to escape poverty and hunger through sustainable agricultural development is an undertaking beyond the scope of any single donor. However this can be overcome if donors, international development institutions, and developing-country partners

work in a more coordinated way. When countries and different institutions want to work independently, solutions to these problems will be impeded.

Women are crucial partners in the fight against hunger and poverty. Women farmers contribute substantially as casual labourers and unpaid family workers in both commercial and subsistence agriculture, including livestock and fishing. They bear a disproportionate burden of agricultural production. Even intensive tasks such as tilling and clearing, which are often combined with childcare and meeting basic family needs. Advancement in agriculture production will be achieved when international community see a need to provide technical assistance and teaching women and other agricultural workers the modern methods of farming.

(v) New Knowledge for Forest Development

Indigenous and modern knowledge play a key role in agricultural development. Such knowledge has historically supported food security's objectives. Attaining potential contributions of agriculture to the world growing population will depend on continued creation and use of new, as well as existing agricultural knowledge at an accelerated rate.

New science in the areas of genomic and biotechnology, and biological control of diseases can potentially improve crop and livestock adaptation to environmental stress, including climatic change, which in turn will improve yields and conserve natural resources. These avenues must be approached in a balanced way. The benefit of this method must be weighed carefully to ensure that its applications would avert the problems affecting food production.

Contemporary research and transfer organizations have not been as effective as they could have been. Improving them will require greater attention to the role of women in agriculture and to the appropriateness of innovations, which must be designed, tested, and transferred to farmers using participatory approaches.

2.3 ENHANCING FOOD SECURITY

Agriculture in developing countries is increasingly moving away from a subsistence orientation and government dominance to commercialization. There are opportunities to accelerate this process in such a way that producers, particularly women, who produce a dominant share of the world's food, become equal partners in the development process and share the benefits.

The rural poor, particularly women, own or have secured access to few assets which they can use to escape poverty. Secured access to land, for example, is often a binding constraint, and the poor are often left to cultivate

the marginal areas. The productivity of their two main assets, i.e. land and labour, is very low, but can be significantly improved through intensification and diversification of production systems. Potential strategies include matching production with natural resource endowments, integrating crop and livestock production, and employing agro-forestry technologies.

To achieve the above, the following steps are recommended:

- Improve access, good management, and land administration
- Diversify and intensify agricultural systems
- Reduce post-harvest losses
- Improve food safety, nutrition education, and use of available foods

2.4 AGRICULTURAL SUSTAINABILITY

Livingstone (1975) clearly states that during the past decade, emphasis in ecology has shifted from ecosystem studies to the evolutionary background of natural communities. This shift to natural community should include the use of school gardens and periurban farming in agricultural intensification. The growing evidence of systematic and evolutionary complexity of ecological environment, where farmers and students are to utilize limited resources in farming practices within the community, requires immediate attention by the local and international communities. Looking at the current population strength of the world, utilization of every resource for the production of crops and animals would be vital in sustainable systems.

The recognition of systematic and evolutionary complexity of ecological phenomena has been a major factor affecting agricultural production as ecologists sometimes lose sight of the organisms and ways of remineralizing the lost nutrients, while in pursuit of transferred calories or cycled geochemical (Livingstone, 1975). Recognition of this complexity would result in dealing with all the factors affecting sustainable agriculture more realistically, as indicated by Livingstone (1975). To better understand the ecosystems, agriculture education should start from the grassroot level where secondary and high school students are introduced to the new scientific methods of food production. The implementation of this would mean setting up of demonstration farms in schools at all levels where research should be conducted on more vulnerable garden crops and testing various nutrients using natural methods in amending the soil fertility. This would create an awareness among the students at secondary and high school levels of the phenomena governing food production.

Pearce's (1994) review indicated that only a few groups of individuals and institutions/organizations have recognized the concepts that have attracted the attention of political, popular, and academic institutions to

sustainable development. Significantly, "sustainable development" now figures as a goal in dozens of national environmental policy statements by various research institutes and young scientists.

Due to a long-term use of soil by humans in different communities for agricultural production, most of the nutrients have been depleted. There is a growing recognition, amongst both policy makers and specialists, that soil degradation is one of the root causes of declining agricultural productivity in Sub-Saharan Africa and other parts of the world. Soil is much more an integral component of natural and human managed ecosystems that there exists a multitude of concepts relative to the nature and functions (Buol, 1995). The diversity of concepts of soil is compounded by the continuance of its properties on the landscape, and geographical limitations of each person's scientific experience. The consequences of allowing productivity of African soil resources to continue on its present downward spiral would be severe, not only for the economies of individual countries, but also for the welfare of millions of rural households depending on agriculture for meeting the requirements for their welfare (Expert Consultation, 1999).

2.4.1 Future Pace of Agricultural Production

No question is more important for the future of humanity than whether growth in agricultural production can keep pace with the increasing population and income driven demand for food (Naylor, 1996). This concern is certainly not new; for several decades scholarly attention has been devoted to issues of agricultural productivity, land use change, and population growth. The vulnerability of agricultural systems throughout the world has increased the number of natural resource constraints and global environmental changes which spawned a new era of literature. As the world is currently posing questions on sustainable agriculture, would there be a contribution when there are challenges on setting up vegetable farms in high schools? Would the establishment of school gardens provide food for nearby communities? The answer is yes. The growing of crops within schools will provide food for both the school community and nearby community people. This has been evident from my 10 years of teaching experience in high schools and with the establishment of demonstration plots, as food for both teachers and students within the community was provided at more reasonable prices.

The review conducted by FAO (1994) states that there should be an intensification of agriculture in a global form. The intensification of agriculture over the years has shown an impressive production of grains and crop yields in the past decades (FAO, 1994). Intensification of agriculture without adequate restoration of soil fertility may threaten the sustainability

of agriculture (Roy et al., 2003). Continuous cropping without adequate restorative practices may endanger the sustainability of agriculture. Farmers and students should understand that nutrient depletion is a major form of soil degradation. A quantitative knowledge on the depletion of plant nutrients from soils will help them understand the state of soil degradation and may be helpful in devising nutrient management strategies (Roy et al., 2003). This group can acquire this knowledge when being involved in a research either through school garden demonstration or participating in improved agricultural programmes.

World population is increasing daily, and as the population increases more food is needed to satisfy their needs. The involvement of high school students will contribute towards food availability and help in further research for the advancement of agriculture. As clearly pointed out by FAO, the intensification of agriculture in a global form has increased the production threefold of cereal crops during the past 60 years. The growth of grains has risen even in many Sub-Saharan African countries over the past decade (FAO, 1994). However, the production per capita has remained stagnant mainly due to extremely large population increases. The current research should focus on involving students at all levels in agricultural production, as it will definitely help in the eradication of food shortage in future.

2.4.2 Assessing Agricultural Sustainability

FAO (2002) indicates that the global population will continue to expand at a rate of 1.1% until 2015 and decrease thereafter. United Nations population projection also states that world population has continuing growing from 5.7 billion in 1995 and it is expected to reach 9.4 billion in 2050, 10.4 billion in 2100, and 10.8 billion by the year 2150. The projection is said to stabilize within the range of 11 billion in 2200 (Gold, 1999). Today, the rate of population increase is very high in many developing countries. In these countries, population factor is combined with rapid industrialization, poverty, political instability, and large food imports and debt burden which have made long-term food security very urgent for the world growing population.

As clarion calls for the new generations, the need for growing more food for the world population has called for sustainable agriculture. As defined by FAO and other agricultural institutions and scientists, sustainable development is the management and conservation of natural resource and it is based on the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Sustainable development

conserves land, preserves water, plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable (FAO, 1994a).

Lynam and Herdt (1989), defined sustainability in agriculture as systems rather than doing singular analyses of inputs and outputs, just because crop varieties and inputs produce nothing in isolation. But only when combined as components of a system do they produce output (quoted in Herdt and Steiner, 1995).

The concept of agricultural sustainability has three dimensions (biological, economic, and social) that are important in determining the future viability of intensive agricultural production (Herdt and Steiner, 1995). Evidence presented in literature indicates that a number of physical constraints, particularly those related to the depletion and degradation of soil, water, and energy resources, threaten future agricultural growth (Smil, 1994). Literature also shows that farmers and society face large costs with respect to declining resources in agriculture¹. To date, the synergistic effects among inputs have worked in favour of agriculture (Loomis and Connor, 1992; Evans, 1993; Plucknett, 1994; Plunknett, 1995). A major social limitation militating against agriculture is how much society is willing to pay in terms of health and ecosystem damages from increased fertilizer and pesticide use in agriculture (Ruttan, 1992; Naylor, 1997). As stipulated in the EU organic regulations, the use of synthetic substances in crop and animal production will be phased out in 2012. Africa is currently advancing in food production, as the world is currently advancing in agricultural discipline, the need to educate future leaders on the modern methods of food production is highly imperative. The involvement of both higher and secondary school students will play a role in this demand not just to embark only on universities, research institutions and individual farmers.

Changes in agricultural technology, infrastructure, and farm management are needed now more than ever in Africa, literature review indicates that investments on agriculture are not keeping pace of meeting the growing world population. Defining new dimension in the modern world is a new challenge for agricultural improvement.

2.4.3 Sustainability of Food

Farming systems are the meeting point of natural economic and social systems, each of which has its own dynamics. For farming systems to meet the demand there should be simultaneous sustainability in each of the

¹Literature review as used in this book means nearly all the literature used in preparing the materials in this book.

dimensions. Adjusting the dimension to reach a lasting period may be incompactable with sustainability in some parts of the world (Marsh, 1997). Adjustment of these dimensions must take into consideration the environment which is the fundamental factor affecting food production.

The environment has become a major constraint to agricultural progress. Fundamentally, agricultural environment should be able to support sustainability; environment is a prerequisite for social and agricultural sustainability. Redclift (1987) claims that poverty reduction is the primary goal of sustainable development, even prior to addressing environmental quality. Poverty is increasing in the world in spite of global and national economic growth. Poverty reduction has to come from qualitative development, from redistribution and sharing, from population stability, and from community sodality, rather than from throughput growth (Redclift, 1986, 1994).

Politicians are determined to achieve difficult task of increasing food production. Meeting these tasks require sustainable development, social integration, environmental and economic sustainability. The moment the term development is introduced, the discussion becomes quite ambiguous. The achievement of sustainable agriculture would only be possible when certain conditions are overcome. There include understanding the relationship between plant and soil, using the right crops on the suitable soil, having a sound knowledge on nutrient remineralization, controlling pests and diseases and introducing school gardens at all levels.

2.4.4 Can Undernourishment be Strengthened in Africa?

As the world renews its efforts towards alleviating food insecurity in developing countries following the 1996 World Food Summit, the availability of an accurate national level indicator of food insecurity that is comparable across countries has become extremely imperative (Smith, 1998). Just as monitoring food insecurity within countries is fundamental for generating adequate information for programme planning and policy making for individual countries (Babu and Quinn, 1994), monitoring food insecurity at national, regional and global levels is essential for such planning and policy making across countries. Policy planning for the projection of more available food in the world should cover three main purposes: (1) identifying where food insecurity exists and where it is most severe; (2) tracking changes in food insecurity over a period of time; and (3) understanding its causes so that the most effective interventions can be chosen to alleviate it. Food security has been discussed in several articles, however, there is enough food in the world but the developing countries have not got the right tools to secure food for the growing populations. The

major aspect international community should focus on, is the identification of areas where efforts are required for the alleviation of hunger in developing countries. Currently, the most widely employed national level indicator of the prevalence of food insecurity is a measure of 'chronic undernourishment' developed by the Food and Agriculture Organization (FAO) of the United Nations. The measure gives the number and proportion of people in each country who consume insufficient dietary energy to meet their requirements.

The issue of undernourishment in Africa led to a research conducted by Ghana and Nigeria on cassava production. Over the years, the research carried out on this crop has helped reduction of undernourishment by 10% since 1980 (FAO, 2000). The undernourishment, which was over 30% points in Africa, has drastically reduced due to the intensive research conducted for more conducive conditions needed for the development of cassava.

Like in the case of cassava, high school students can be exposed to the management and production of different crops through the establishment of vegetable gardens in their respective schools. The introduction of gardens in schools will guide them on the overall strategies needed to improve crop production, and the production of more nutritious crops in particular. Producing more food may not be the only yardstick for the introduction of gardens in schools, but also to establish means of preserving food crop in a natural form without the involvement of chemical substances (organic). Beside, as the world calls for sustainability, their contribution will, no doubt, assist in sustainable agriculture in future.

Recommendation

Development requires a sound land use planning. Land use planning needs a biophysical and socio-economic evaluation component, since socio-economic conditions may change instantly and the biophysical environment is more stable.

In developing countries, information is required at three levels corresponding to approximate resolutions of 1:200,000 (department), 1:50,000 (district) and 1:10,000 (village). An appropriate tool for inventory at these scales is SOTER which offers corresponding map units (terrain unit, terrain component, soil component). Experiences at three different sites based on Geographic Information Systems (GIS) and relational databases (RDBMS) have been recently reviewed (van Engelen, 1993). Overall, SOTER is an adequate tool, but in order to ensure consistency and applicability, some changes with regard to the original structure are necessary.

To aid the contribution of students towards sustainability, community people would have to play a role by making more land available for schools.

The problem developing countries face in agriculture is caused by rapid urban growth. This has claimed most of the land supposed to be made available for community schools for carrying out research on suitable crops to be grown within the communities. By controlling this growth and paying proper attention to students' agricultural land, the problem of food insecurity may be resolved.

2.5 SUGGESTIONS ON HOW TO PROMOTE AGRICULTURAL DEVELOPMENT

- Governments must commit themselves to a coherent and comprehensive vision of agricultural and rural development.
- Maintaining sound and stable macroeconomic and trade policies that encourage investment in agriculture.
- Strengthening human capital in rural areas through health and educational services and access to productive resources.
- Establishing a strong institutional environment that improves access to markets, ensuring dissemination of information, standards setting, and provides an adequate legal and regulatory framework for development.
- Enabling research and extension services to develop productive and robust technologies under farm conditions.
- Upgrading marketing systems, transport and communication infrastructure to support farmers' access to seasonal and longer-term capital and inputs, and providing them with strong price incentives.
- Safeguarding natural resources and environment capacity.
- Providing marketing assistance.

2.6 FACTORS AFFECTING FARMERS

The factors affecting farmers today may be much more complex than those faced by developing countries which achieved sustained agricultural growth in the last three decades. New and emerging challenges confronting them can be identified under three broad headings:

- Overcoming their marginalization resulting from integration of markets due to globalization and liberalization.
- Adapting to technological change.
- Coping with the new institutional environment.

2.6.1 Globalization of Markets

Globalization and liberalization are becoming more vulnerable to changes in the world market conditions, on account of their small economic size and

their increasing reliance on imports for food supplies. Their problems have been compounded by the long-term decline in real prices of their major primary commodity exports, despite some temporary increases experienced in the early 1990s (<http://www.fao.org>). The consequent decline in the commodity terms of trade has reduced both the incentives to engage in the production of tradeable gains and economic stimulus of agricultural products.

2.6.2 Technological Challenges

Keeping pace with the increasing domestic demand for food, meeting requirements for enhancing competitiveness and ultimately raising rural incomes, necessitate raising agricultural productivity. Sustained agricultural growth requires more ingredients than that of 'the green revolution'. Investment in irrigation and rural infrastructure, human development and institutions will contribute immensely towards overcoming these challenges. New developments in biotechnology may also pose further threats to technological challenges.

2.6.3 Measures to Accelerate Agricultural Development

- Emphasis needs to be given for increasing the production of tradeable products (cash crops).
- Determining the most appropriate roles relevant to government agencies, donors, civil organizations, and commercial entities.

2.6.4 Recommendations for National and International Actions

- Meeting the new challenges facing agriculture will further accelerate development.
- Further emphasis on macroeconomic and sectoral incentives has a great role to play in agricultural sustainability.
- Strengthening institutional capabilities will promote further research on agricultural advancement.
- Raising and sustaining productivity and competitiveness will broaden markets.
- Diversifying production and trade should be the focus of investors, government and individuals.
- Improving access to foreign markets will encourage more farmers to enter into the agricultural domain.

Land is the top layer of earth's surface containing essential elements needed in nature to support the growth of crops and animal life. Land is a very important asset for the majority of people in the world especially in Africa. Current estimates show that about 70–80% of Africa's population relies directly on agriculture for subsistence, existence and income generation.

Africa's landscape and environment perform a variety of essential ecological functions in providing water for drinking and fisheries for the population. Land plays a great role in a country, as it is used for growing crops, animal production and erection of buildings. Despite the relatively low proportion of people living in Africa, a lot of town-dwellers retain a very high level of interest and possession of their land.

In Africa, distribution of land is an issue of discussion and cultural inheritance. Many West African systems are still based on customary rights associated with cutting a field and settling especially in areas where land is relatively abundant. The need to sort out the contradictions between customary and statutory tenure systems, provide communities with greater formal decision-making powers over how the resources on which they depend on may be used. Strengthening local capacities to carry out these tasks effectively is the main issue of concern (Toulmin and Simon, 2000).

3.1 LAND TENURE

Land tenure refers to the methods in which land, other natural resources, etc. are held and used by communities, individuals and governments. It refers to the rights, obligations of landholders and their users. Land tenure is one of the crucial determinants of how land management and resources are used. Rights are always balanced by obligations or duties. For example, fines may be imposed on a livestock owner if his animals damage crops on the fields of the landholder. Security of rights always involves some authorities enforcing

these obligations, imposing sanctions that protect land right holders, and mediating between conflicting claims. Land tenure, therefore, involves some methods of governance, that encouraged land administrative functions like record keeping and management principles.

Land tenure in Africa has undergone an evolutionary transformation from simple systems to complex ones since the humanization of Africa. The political independence in Africa, land use and land tenure have been characterized as simple subsistence modes of production, which is based on communal or egalitarian land tenure systems (Yudelma, 1964; July, 1975).

Subsistence production and communal land tenure systems are still prevalent in many parts of sub-Saharan Africa. Land use over the years has evolved in certain regions from simple subsistence and shifting cultivation to sedentary or permanent types. Land tenure evolved over the passage of time from communal forms to those types in which emphasis is given to individual landowners. Land can be owned and controlled by the government of a country, which in turn places it under the control of local government ministries. Beside government land, a group of persons can temporarily own a piece of land for a certain number of years on rental basis, however, in this kind of ownership, permanent crops or buildings are not permitted.

3.2 LAND USE

Land use in Africa refers to the usage of any given piece of land for a period of time, under prevailing environmental conditions. Land use can be classified into agricultural use and non-agricultural use. The technological conditions of land use have undergone an evolutionary transformation from simple game hunting and gathering, to the more complex sedentary commercial cultivation systems in modern agriculture.

Pritchard (1979) explained in theory and publication that land use in tropical Africa evolved from game hunting by the Bushmen in the Kalahari Desert. Other nomads in Zaire especially where population is sparse to bush fallowing, do returned to the abandoned patches of land to cultivate crops as soon as the soil and vegetation have been replenished. However, bush fallowing practices are only possible in an area where there is less population.

3.2.1 Types of Land Tenure Systems

Land tenure may be defined as the terms and conditions on which land is held, used and transacted. Land tenure reform is the planned changes in the terms and conditions of land found in a location. The fundamental goal of

land reform is to enhance and to secure people's land rights. This may be necessary to avoid arbitrary evictions and landlessness.

According to FAO (2002) definition, land tenure is the relationship, whether legally or customarily defined, among people, as individuals or groups. Land tenure is an institution, like rules, invented by societies to regulate behaviour. Rules of tenure define how property rights to land are to be allocated within societies. Rules define how access can be granted to rights to use a specific land and its control, and also the transfer of land from generation to generation, or from one individual to another, as well as the associated responsibilities and restraints. In simple terms, land tenure systems determine who may use the resources within a given period under certain conditions.

Land tenure is an important part of social, political and economic structures. It is multi-dimensional, bringing into play social, technical, economic, institutional, legal and political aspects that are often ignored but must be taken into consideration. Land tenure relationships may be well defined and enforceable in a formal court of law or through customary structures in a community. Alternatively, they may be relatively poorly defined with ambiguities open to exploitation (FAO, 2002a).

3.2.2 Land Rights

On the issue of land rights, this is brought about in response to concern for food security and poverty alleviation. Development agencies and organizations have introduced strategies that help to build assets and promote self-reliance of poor people and communities. Interventions include helping poor people protect and enhance their natural resource base, improving access to agricultural land through resettlement schemes, and ensuring food security of the vulnerable, including women, minorities and indigenous groups (FAO, 2002). The most important issue is helping them protect their rights in the various communities.

(a) Individual Land Rights

The most prevalent type of land tenure systems in pre-colonial Africa are generally abundant lands and sparse populations. The individual families under these conditions within a given village usually acquire land by clearing virgin bushes. Land transfers could also be obtained by inheritance (Conroy, 1945). Once an individual acquires a piece of land under inheritance, the community protects his/her rights.

In this method of land rights, members who traced their heritage from a common ancestry were exclusively reserved access to agricultural land for use. As a rule, transfer of land rights among families between matrilineal

relatives or friends, and the land rights of a deceased person were in all probability taken over by matrilineal relatives.

The advantage in this system is that land can be sold when the owner is facing financial difficulty. The individual persons can also use it to obtain loans from banks when money is needed and the land will serve as a coelenterate. The owner has right to grow tree crops without any restriction. Buildings can also be erected on the piece of land. The major disadvantage is that the land can be fragmented as generations pass. It also discourages large scale farming as some individuals may not be willing to carry out farming and would not be interested in giving their piece of land to those interested in farming.

(b) Communal Land Tenure Systems

This form of land tenure is associated with the community right. Skinner (1964) shows that in the pre-colonial semi-feudal agrarian-social structure of the Mossi Empire in Burkina Faso, the King and the chief classes controlled land and assigned land rights to individual community members. Anyone living in the community must acquire land through the Kings or chiefs. Sometimes this kind of land tenure system brings enmity among community members when the land is not equally shared. However, the system does increase agricultural production as most members living in the community have access to a portion of land.

(c) Landlords and Tenants

Feudal systems of land tenure and feudal relations of production emerged in many different parts of Africa. In the south and west of Ethiopia, feudal land tenure emerged especially towards the end of the 19th century. The tenants/serfs usually paid rent in kind, which varied depending on the demands of the landlord. Usually tenants were expected to pay 50% of the harvest. In some cases, the rent would be higher than the cost expected to be harvested by the tenants. Tenants who defaulted in their obligations could be evicted by the landlords and become landless (Gilks, 1975). This method, however, discouraged a lot of farmers who were interested in large scale farming, as a result of exorbitant prices in land rent.

(d) Leasehold System

A lease is a document that is a legal binding agreement between the government and the lessee. It is a written document that sets out the rights and obligations of lessees and states the purpose for which the land can be used.

One of the key obligations of lessees is to develop the land in the time prescribed in the lease document. Leasehold system under the control of government warrants the lessee to have access and use the land that is

described in the lease for his or her benefit and can remain as the owner of that land for the term of the lease period. The person under this system is, however, bound by certain rules and regulations. In most cases, the person using this type of land is advised not to erect permanent buildings as the land may be returned back to the rightful owner at the end of the lease period.

3.2.3 Factors Affecting Land Availability

The most important factors affecting land availability in West African countries are:

- ❖ Physical factors like topography, soil type, etc.
- ❖ Socio-economic factors which include industrial development and population pressure.
- ❖ Environmental factors like climate, etc.

Weathering

Weathering is a term used to describe the changes which rocks undergo to form soil. It involves a complex series of changes that in turn result in disintegration of rocks. The disintegration from mineral particles forms soil. Weathering processes may be classified into three categories, namely, physical, chemical and biological. The physical process involves the activities of water or ice and wind disintegrating rocks into smaller fragments. The biological process involves the activities of living organisms such as earthworms, termites and other soil organisms, whereas the chemical weathering usually involves dissolution of minerals in water and atmospheric air like carbon dioxide and oxygen.

Physical or Mechanical Weathering

Physical Weathering

This breaks down rocks into smaller pieces thereby increasing the surface area in which chemical weathering can occur. Chemical weathering promotes decomposition of minerals in rocks to a lesser resistant mineral. Physical and chemical weatherings reduce rocks to easily erodable weaker materials.

Many agents such as temperature, frost action, organic activity, and abrasion cause mechanical weathering. Due to temperature variations over a period of time, it allows the rock to expand and contract repeatedly causing curved-shaped pieces to break off. Dumas (1997) explained that frost action occurs as water seeps into tiny cracks in the rocks that freeze at night. When the ice expands, it breaks down rock fragments. Biological activity also occurs as plant roots slowly pry apart the rock, as the plant grows larger.

Biological Weathering

Rocks undergo a process of weathering which is a primary source of some essential elements for organisms, except nitrogen and carbon. Weathering has been accelerated under the influence of biota. The study of biological weathering began in the end of 19th century. However, the role of bacteria (Eubacteria and Archaea) has attracted interest on weathering over the past years. Fungi in rock weathering were not given special attention in the past. But current research on weathering has been focused on fungal and bacteria, as their role in breaking down of rocks is increasingly an important focus of biogeochemical research. The breaking down of rocks by algae and bacteria has been recognized for some time in a variety of environment. However, further research on weathering may reveal the roles of organisms in weathering processes.

Mellor, 1922; Palmer, (1989) mentioned that various biological agencies are considered very significant in the deterioration of building materials. The effects of rock breakdown in different environments, particularly in hot deserts and Antarctica according to Friedmann et al., 1947, Friedmann, 1971; Broady, 1981; Kappen et al., 1981; Friedmann and Weed, (1987) are seen to be aided by the activities of soil organisms. The absence of organisms during weathering may impede the process of biological weathering which gradually reduces the rate of soil formation.

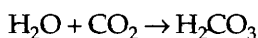
Chemical Weathering

This is the process by which rocks are decomposed, dissolved or loosened by chemical processes to form residual materials. It involves the breaking down of minerals resulting to changes in rock composition thereby replacing strong minerals with weaker ones. Most chemical weathering is caused by water. Water can dissolve most minerals that hold rocks together. There are different chemical reactions associated with chemical weathering. These include:

Carbonation

Carbonation is the process whereby carbon dioxide is dissolved in rainwater or moisture in surrounding air to form carbonic acid and which later reacts with the minerals in the rock. This process thus weakens the rock. The slightly acidic rainwater is then capable of dissolving certain minerals in the rocks.

Chemical reaction: Calcium Carbonate + Water + Carbon Dioxide → Calcium Carbonate (soluble).



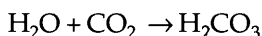
Though weak, when carbonic acid is combined with a mineral like calcite (CaCO_3) common to limestone, calcium and bicarbonate ions are released and carried off by groundwater (Thornbury, 1969).

Chemical equation for carbonation: $\text{CaCO}_3 + \text{H}_2\text{CO}_3 \rightarrow \text{Ca}^{+2} + 2\text{HCO}_3^-$

Dissolution

It is believed that dissolution occurs when rocks and/or minerals are dissolved by water (McConnell, 1998). The minerals dissolved are transported from the area of breaking down leaving a space in the rock resulting in the formation of caves in limestone areas.

Rain + carbon dioxide $\rightarrow$ carbonic acid

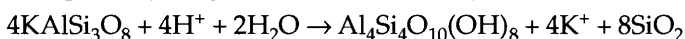


Hydrolysis

This is the chemical reaction between minerals in the rock and hydrogen in rain water. For example, during hydrolysis, the feldspar in granite changes to clay mineral which crumbles easily, weakening the rock and causing it to break down. It may also be described as the ionisation of carbonic acid into two ions (hydrogen (H^+) and bicarbonate (HCO_3^-)). Feldspar is the most common mineral in rocks on the earth's surface that usually reacts with water to form a secondary material like kaolinite.

Chemical combination:

feldspar + hydrogen ions + water $\rightarrow$ clay + dissolved ions



Oxidation

Oxidation is the process in which oxygen chemically combines with another substance. The result of oxidation is the formation of an entirely different substance. When carbon dioxide dissolves in water, a weak acid called carbonic acid is formed. This acid can dissolve some types of minerals (Dumas, 1997). In this process, oxygen reacts with iron in minerals to form iron oxide minerals such as hematite (rust) leading to the weathering process of rocks. When oxygen combines with iron, the reddish iron oxide hematite (Fe_2O_3) is formed (Thornbury, 1969):



3.3 ROCK FORMATION PROCESSES

Rocks are described as the physical mixture of two or more minerals, though they may consist of a single mineral variety. The proportion of various

minerals combined during formation determines the type of rocks formed. The mineral composition can be classified as primary rock forming minerals and secondary rock forming minerals. Usually, the mineral compositions of rocks are inorganic and have a definite chemical composition.

Primary rock forming minerals usually include, quartz, feldspar, micas and olivine. The secondary rock forming minerals include oxides of aluminum and iron, clay minerals, carbonates and sulphates, sulphates of calcium, magnesium and phosphate.

In general, rocks are basically of three types and include igneous, sedimentary and metamorphic. As the earth cooled, great masses of rock of varying weight and composition buried many kilometres deep in the earth were converted in rocks. These rock materials are believed to surround the molten mass known as magma. Magma is the term usually used to describe molten material lying on the earth. However, molten rock may contain some suspended crystals or dissolved gases as well.

Igneous Rocks

The formation of igneous rocks was due to the effect of high temperature (5,000°C) on molten materials lying on the earth's interior for years. When molten rock cools and solidifies, it becomes mineral crystals which are then called igneous. There is a variation of melting temperature for different compositions of magma. Some of this molten rock remains inside the earth and some are ejected as lava onto the earth's surface during volcanic eruptions. The process of forming mineral crystals is called crystallization. As the mineral crystals form, they join together or interlock into masses of igneous rocks. The further breakage of the igneous during change of weather and transformation led to the formation of sedimentary and metamorphic rocks.

As a result of variation of melting temperatures of magma during cooling, several compositions are formed. It is highly typical for silicon tetrahedra to form first, and later join with other ions to form nuclei for crystal growth. The minerals with the highest melting points crystallize first and their crystal growth continues unimpeded as long as the surrounding material remains molten. As crystallization gets completed, a solid mass of interlocking crystals of different sizes become igneous. Igneous rocks include granite, gabbro, rhyolite, and basalt.

Sedimentary Rocks

These are derived from pre-existing rocks of all types. The rocks forming sedimentary types were broken down by the activities of weathering agents like frost, wind, rain, river, ice and sea. The elements produced by these

agents were moved from their origin to be deposited elsewhere. The materials derived from the broken elements by river, sea and sand were cemented together by the process of diagenesis. The consolidated materials constituted the sedimentary rocks. The ones not consolidated were the sediments. Sedimentary rocks can be distinguished on the basis of their origin. This class of rocks is divided in clastic, chemical and organic sediment.

The clastic sediments are usually the fragments of other existing rocks transported by wind, ice or water. They can be grouped corresponding to size of the fragments in conglomerates, sandstones, siltstones and mudstones. The chemical sediments are the results of high evaporation in shallow area basins and the chemical precipitation of dissolved materials as carbonated limestone, dolomite, sulphate (gypsum) and chloride (NaCl, KCl). The organically formed rocks are derived from animal and plant materials. The materials include peat, coal and lignite that are deposited as a result of accumulation of plant materials (Akinsanmi, 1975).

Metamorphic Rocks

These are derived from pre-existing sedimentary or igneous rocks. They are formed by the activities of the agent of pressure, heat and chemicals. This group of rocks is classified into two, i.e., foliated and non-foliated. The individual mineral grains are usually parallel to one another in foliated type. Examples of foliated type include muscovite and biotite. The non-foliated rocks do not possess cleavage while the foliated rocks possess cleavage. Examples of non-foliated type include gneiss made from quartz, feldspar and some dark minerals. Schist is another example, but its origin is affiliated to sandstone, shale, limestone and buried larva. This rock possesses undulating planes that have been formed by cleavage as a result of pressure. Examples of metamorphic rocks include quartzite, marble and slate.

3.4 SOIL AND ITS FORMATION

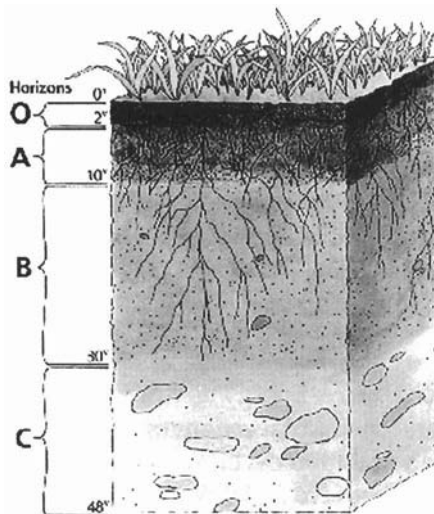
Soil is a central basis for all agricultural activities (Alfoeldi et al., 2002). It is one of the most important natural resources for crops. Proper attention must be paid to it for the maximum support of agriculture. Most organic farmers do not compensate for a loss in fertility of soil by inputs of synthetic nutrients, therefore, the building and maintenance of soil fertility should be the central objective of organic agriculturists (Lampkin, 1990; Stolton et al., 2000). The impacts of organic farming on soil properties have been covered extensively by researchers over the years with a special focus on the relevant parameters of organic matter content, biological activity and soil erosion.

Thorough comparisons of relevant soil parameters of conventionally and organically managed soils in Switzerland proved the following:

- Organic matter content is seen to be higher in organically managed soils than in exclusively mineral fertilized conventionally managed soil, as a result of organic fertilization methods. High organic matter content can help avoid soil acidification.
- Organic soil management improves soil structure by increasing soil activity, therefore, reducing the risk of soil erosion.
- Organic crops profit more from root symbiosis, and are better able to exploit soil.
- Organically farmed soils have significantly higher biological activity than those of conventionally managed soils, due to the presence of a large number of earthworms, fungi, bacteria, and other micro-organisms.
- Organic management promotes the development of soil fauna like earthworms and other ground arthropods, thereby improving the growth conditions of crops.

3.4.1 Factors Affecting Soil Formation

Soil research has proved that soil profiles are influenced by five separate, yet interacting, factors: parent material, climate, topography, organisms, and time. Soil scientists call these the *factors of soil formation*. These factors give soil profile their distinctive characters.



Source: <http://www.nesoil.com/plymouth/formation.html>

Fig. 1 A soil profile

The interaction of the five soil-forming factors (time, climate, parent material, topography and organisms, i.e. plants' and animals' life) results in the development of a soil profile. Soil profile is a vertical section of the soil layer beginning from the surface and extending downward into the unconsolidated underlying material to a soil depth of 60 inches or more. The topsoil called "A horizon" is the outermost layer of soil; it is parallel to the soil surface, with distinct characteristics produced by soil-forming processes as illustrated in the above Figure 1. It usually includes the organic layer in which plants have their roots and the farmer turn over during ploughing. The physical and chemical characteristics observed within the soil profile are the basis for differentiating soil from another.

(a) Parent Materials

Soil parent material is the material that soil develops; it may be a rock that has decomposed in place, or material that has been deposited by wind, water, or ice. The character and chemical composition of the parent material plays an important role in determining soil properties, especially during the early stages of development (Ritter, 2003).

Soils developed on parent material that is coarse grained and composed of minerals resistant to weathering are likely to exhibit coarse grain texture. Fine grain soils develop where the parent material is composed of unstable minerals that are readily weathered (Ritter, 2003).

Parent material composition has a direct impact on soil chemistry and fertility. It is rich in soluble ions (calcium, magnesium, potassium and sodium) which are easily dissolved in water and made available to plants. Limestone and basaltic lava both have a high content of soluble bases and produce fertile soil in humid climates. If parent materials are low in soluble ions, water moving through the soil removes the bases and substitutes them with hydrogen ions making the soil acidic and unsuitable for agriculture. Soils developed over sandstone are low in soluble bases and coarse in texture, which facilitates leaching. Parent materials influence on soil properties tend to decrease with time as it is altered and climate becomes more important (Ritter, 2003).

(b) Climatic Factors

Soils are assumed to show strong geographical correlation with climate, especially at the global scale. Energy and precipitation, however, strongly influence physical and chemical reactions on parent materials (Ritter, 2003). Climate determines vegetation cover, which influences soil development. Precipitation in the atmosphere does affect horizon developmental factors in relation to translocation of dissolved ions through the soil. Climate is also

believed to influence soil properties since the influence of parent material during soil formation is low.

(c) Soil Topography

Topography describes the shape of a land in a particular location. The shape of land surface, its slope and position on the landscape, greatly influence the kinds of soils formed. Topography has a significant impact on soil formation as it determines runoff of water, and its orientation influences microclimate which consequently affects vegetation. The formation of soil depends on the parent materials which need to lie relatively undisturbed to enable soil horizon processes to continue. Water moving across the surface strips parent material away impeding soil development. Water erosion is more effective on steeper land according to soils investigated by various scientists.

(d) Time

The formation of soils is a continuing process and it generally takes several thousands of years for significant changes to occur. It takes approximately 14,000 years for American soil to form, 10,000 years in Europe and 100,000 years in Africa. This formation is however depending on the region and location. Plymouth soils are considered to be relatively young soils with slight alteration of parent material and weak soil horizon development. Most of the soil orders mapped in Plymouth County are Inceptisols, Entisols, and Spodosols. In general, time is considered to be the most important factor affecting the formation of soil, as the length of time taken during soil formation determines the type of soil that would be formed.

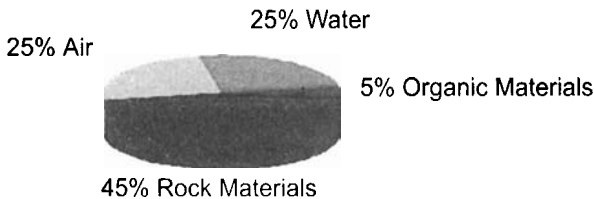
(e) Soil Organisms

Plants, animals, microorganisms, and humans affect soil formation. Animals and microorganisms mix soils and form burrows and pores. Plant roots open channels in the soils. Different types of roots have diverse effects on soils. Grass roots are “fibrous” near the soil surface and decompose easily, adding organic matter. Taproots open pathways through dense layers. Microorganisms affect chemical exchanges between roots and soil. Humans can mix the soil so extensively that the soil material is again considered parent material (United States Department of Agriculture, USDA, 2005).

The native vegetation depends on climate, topography, and biological factors plus many soil factors such as soil density, depth, chemistry, temperature, and moisture. Leaves from plants fall on the surface and decompose on the soil. Organisms decompose these leaves and mix them with the upper segment of the soil. Trees and shrubs have large roots that may grow to considerable depths (USDA, 2005).

3.5 SOIL COMPOSITION AND PROPERTY

The physical properties of soil largely determine the manner in which it can be used. Properties such as waterholding capacity, permeability to water, aeration, plasticity and nutrient-supplying ability are influenced by the size, proportion, arrangement and mineral composition of soil particles. The proportion of the four major components of soil—inorganic or mineral particles, organic material, water and air, vary greatly from place to place and with depth. The amount of water and air in the soil fluctuates from season to season, but the proportion of primary solid components of the soil, however, remains unchanged. The universal components of soil in percentage are listed in Fig. 2:



Soil = rock materials + organic materials + water + air

Source: McConnell, 1998

Fig. 2 Soil Composition

Particle Shape and Size

The particles of soil vary in shape (spherical to angular) and structure. The size is different from gravel, it varies between sand and fine clay. The effective international sizes considered are illustrated in Table 1.

Table 1: Particle sizes based on USDA and International Classification Systems

Soil	International system	Alterberg System
	(Particle diameter in mm)	Particle diameter in mm
Gravel	2 and more	2 and more
Very coarse sand	2-1	-
Coarse sand	1.0-0.5	2.0-0.2
Medium sand	0.5-0.25	-
Fine sand	0.25-1	0.2-0.02
Very fine sand	0.10-0.05	
Silt	0.05-0.002	0.02-0.002
Clay	Less than 0.002	Less than 0.002

Textural Classes

The proportions of various particles of different size groups of soil constituents are called soil texture. The main soil texture classes include: clay, sandy clay, silty clay, clay loam, sandy clay loam, silty clay loam, loam, sandy loam, silt loam, sand, loamy sand and silt.

The silt particles are found intermediate between sand and clay particles. Mineralogically, the particles of silt are similar to those of sand and are largely composed of primary minerals. They are more reactive than sands particles because of the higher specific surface (<http://www.krishiworld.com/html//soils3.html>)

Silt

Silt consists mainly of very small quartz particles. Each particle has a large surface area; it is smooth and powdery. Silt is found in between sand and clay particles. When water is applied to silty soil, the air is trapped in the pores thereby preventing it from moving freely into subsoil, leaving the moisture in the topsoil. The higher the amount of silt in the soil, the greater the amount of water available in the soil and the greater the amount of water available to plants (Akinsanmi, 1994).

Clay

The clay fraction controls the important properties of the soil and it is composed of secondary minerals—crystalline alumino silicates. It has high specific surface which is more reactive. Its ability to retain water and nutrient is very high. The textural classes are different not only in the particle size analysis, but also in their bearing on some of the important factors affecting plant growth. The clayey soils can hold more moisture, but have high wilting percentage:

Factors affecting plant growth include:

- (i) Moveability and availability of water
- (ii) Aeration
- (iii) Workability
- (iv) Content of plant nutrients

Sand

Sandy soils are very permeable and are well drained with less water retention. They require frequent irrigation for successful crop growth compared to fine textured soils. The rate of water capacity of sandy soil is

low. Unlike clay soil, it is usually waterlogged resulting in poor aeration and workability. The moderately fine textured soils, e.g. loams, clay loams, or silt loams, are by far the excellent soils for plant growth, as they have the advantages of both sand and clay soils.

Soil Colour

Colour is a ready indicator of soil conditions and some important properties. The colour of soil can be used to determine its strength, i.e., either rich or poor. Red, yellow or brown colours are usually related to the different degrees of oxidation, hydration and diffusion of iron oxides in the soil. Dark colours are associated with one or a combination of several factors, including impeded drainage conditions, content and state of decomposition of organic matter.

Soil Pore Spaces

The portion of soil occupied by air, water between minerals is referred to as soil pore spaces. Pore spaces are usually determined largely by the structural conditions of the soil. Results of several researchers clearly show that sandy soil has low pore space of about 30%, and that of clay is approximately 50–60%. However, clays possess greater total porosity for plant growth than sands. The pore spaces in sand are considered larger. Water passes through easily without retention.

Soil Density

From several investigations carried out by soil scientists, it was discovered that soils with larger particles are usually heavier in weight per unit volume than those with smaller particles. Different soils are based on individual densities and their constituents according to their proportionate contribution. The bulk density or apparent density is the weight per unit volume of dry soil as a whole.

In mineral soils, the true density of minerals varies within narrow limits of about 2.5 to 2.7 and the apparent density range is between 1.2 and 1.6. This is also determined based on regions.

Soil Temperature and Heat

Soil temperature is described as one of the most important factors that control microbiological activities in the soil and all the processes involved in plant growth. For seed germination and other biological activities, heat is imperative.

The required temperature needed by seeds for germination varies from crop to crop. Crops like wheat, barley, and peas are grown in India and Europe during winter with relatively low temperatures as compared with maize, groundnut, cassava and cotton grown in tropical regions with high temperature. Microbiological activities are retarded by low soil temperature. Low temperature retards nitrification processes and other activities of microorganisms for decomposition processes. This effect will no doubt slow down the nutrient usage by the plant, and growth will be adversely affected.

As a result, soil temperature is considered to be very important in soil taxonomy and the provision to use it as a differentiating criterion at the family level of categorization should be encouraged.

Soil Air

Soil air is an important component of soil. The restriction of soil aeration adversely affects root development, processes of respiration and other essential biological processes involved in biomass turnover and nitrification process by symbiotic and non-symbiotic activities. It is, therefore, important to understand the content of soil air and its composition. Experimental results of authors have previously mentioned that soil air depends on its texture. Soil may have pore space of 30–60%, but the pore space that is not filled by water is usually occupied by air.

Plasticity and Cohesion

Plasticity enables a moist soil to change shape on the application of force and retain its shape even when the force is withdrawn. Looking at this aspect, sandy soils may be considered to be non-plastic and clayey soils are plastic. Cohesion helps particles to stick to another, while adhesion helps particles to detach. Plastic soils are cohesive. Plasticity and cohesion reflect the soil consistency and workability of the soil in terms of quality and the tendency to be used for agricultural purpose.

3.6 SOIL ORGANIC MATTER IN SUSTAINING SOIL FERTILITY

Tropical soils are poor in inorganic nutrients and rely on the recycling of nutrients from soil organic matter to maintain fertility. In undisturbed rainforests, such nutrients are recycled via the litter (Medina and Cuevas, 1989). Soil nutrients depend on the mineralization of organic nutrients from plant remains (Mueller-Harvey et al., 1985; Tiessen et al., 1992). Effects of fertilization can be inconsistent because of leaching or fixation of inorganic nutrients.

Farmers should be aware that organic resources play a crucial role in both short-term nutrient availability and long-term maintenance of soil organic matter in smaller holder farming systems in the tropical regions (Palm et al., 2001). Despite this importance, there is little predictive understanding for the management of organic inputs in tropical agroecosystems (Palm et al., 2001).

In West African semi-arid tropics, the continuous cultivation of the soil has led to a drastic reduction of soil organic matter (Bationo and Mokwunye, 1991). Such reductions in the level of soil organic matter have resulted in decreased soil productivity over the years. The addition of organic materials either in the form of manures or crop residue has beneficial effects on the soil's chemical and physical properties (Bationo and Mokwunye, 1991). The amounts of nutrients in crops and crop residue are often several orders of magnitude but higher than the quantity of the same nutrients applied as fertilizers. The return of crop residue for soil fertility improvement cannot be overstressed but it is essential to gather more information on the rates of organic matter decomposition with a view to have a better production through healthy and a fertile soil.

However, despite the adverse effects caused by chemical fertilizers, the use of vermin-compost is still used in Maharashtra, Karnataka and Gujarat States and other parts of the world to improve soil conditions and increasing crop yield and crop quality. The people of Maharashtra, Karnataka and Gujarat States believe that the adoption of vermin-culture technology not only helps in improving soil fertility on a sustainable basis, but it also helps in minimizing the use of chemical fertilizers to the extent of 25 to 50% and increase crop yield by 15 to 20% due to increased supply of all essential elements.

Crop rotations are crucial for organic systems because the leguminous crops used (such as alfalfa and red clover) provide nitrogen (N) and help recycle nutrients, like phosphorus (P) and potassium (K). The presence of deep-rooted crops in the systems of the rotation helps extract nutrients from lower soil depths and return to the surface when the vegetation dies. Crop residues provide carbonaceous biomass upon which soil microfauna (e.g., earthworms and beetles) and microorganisms embark on.

3.7 SOIL MANAGEMENT PRINCIPLES

International agricultural research institutes and researchers from different institutes have significantly contributed towards the development of sound soil management principles to enhance production techniques that are sustainable to both rural and urban development without compromising the

ecosystem functions of soil. Some of the recommendations put forward for soil management after numerous researches and investigations include:

- ❖ Nutrient enhancement
- ❖ Practising tillage
- ❖ Integrating cover crops with multiple purposes
- ❖ Practising soil conservation with a view to control soil loss through erosion
- ❖ Application of organic matter with plant and animal origin
- ❖ Enhancing soil organic carbon pool as an integrator of various soil base functions
- ❖ Integrating sustainability of nutrient cycles

3.7.1 Nutrient Enhancement

In addition to nitrogen from legumes, cover crops help recycle other nutrients on the farm. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), and other nutrients are accumulated by cover crops during a growing season. When green manure is incorporated, or laid down as no-till mulch, these plant-essential nutrients become slowly available during decomposition. Dr. Greg Hoyt once developed a method for estimating nutrient accrue ment by cover crops in order to reduce the soil test recommendation of fertilizer.

Farmers should be encouraged to grow leguminous cover crops because of their ability to biologically fix nitrogen to the soil through symbiotic relationship with *Rhizobia* bacteria living in nodules of roots. The amount of nitrogen that may contribute to nitrogen fixing crops depends on environmental conditions, carbon to nitrogen (C:N) ratios of the cover crop, available nitrogen in the soil and soil microbial activity.

In addition to the quantity of nitrogen available in a legume and cover crop, the rate of decomposition, or mineralization, must be matched with crop N- uptake requirements for optimum yield.

3.7.2 Tillage

Tillage offers a variety of advantages for optimizing crop yield and maintaining soil conditions that promote soil and water conservation. The use of string tillage allows in-row soil disturbance and subsurface nutrient management for optimum crop production. Strips of “no-tillage” rows help reduce runoff and erosion losses compared to more intense tillage systems. Single pass preplanting tillage is less costly than multiple pass options. Tillage contributes towards soil aeration improves soil water holding

capacity. It promotes activities of soil organisms and root penetration in the soil. The use of tillage on a farm adversely (or controls) affects disease outbreak on the field.

Reduced tillage practices help to suppress diseases, most diseases can be favoured as a result of more residues of plant materials on the surface. The major factor by which reduced tillage affects diseases is through the increase of inoculums. Inoculums are terms used for the pathogen propagules that initiate epidemic. The practice of reduced tillage decreases crop debris, which serves as a refuge for many pathogens and destroys voluntary plants that act as a reservoir of pathogens, such as viruses or rusts that require a living host (Bowden, 2000).

Tillage can also affect diseases through changes in microenvironment. Recent studies show that reduced tillage increases soil moisture and decreases soil temperature. The changes, however, help suppress some diseases like dryland foot rot or common root rot. There are numerous other changes in the soil bulk density, porosity, and microbial activity. Tillage has an effect on behaviour of vectors that carry diseases. For instance, aphids that carry barley yellow dwarf virus are less likely to land in fields with abundant crop residue on the soil surface (Bowden, 2000).

3.7.3 Cover Crop Practices/Soil Structure Enhancement

Annual cover crops like rye, barley, oats, ryegrass, vetch, Austrian field peas, and crimson clover are grown during cold season in the northern latitudes to prevent erosion and improve soil nutrients. These crops are grown and destroyed in the early stage with a view to improve soil quality. These crops can be incorporated into the soil as a green manure crop.

Warm season annual cover crops like buckwheat, foxtail millet and Sudan grasses can be used to fill openings in crop rotation sequences. Perennial grass and legume cover crops are commonly used in orchards and vineyards as living mulches. Living mulch systems involving chemically or mechanically suppressed cover crops have also been used successfully in vegetable and field crop systems through temporary suppression of the cover crop with herbicide or mowing (Sullivan, 2003).

Cover crops play a role in soil structure improvement and act as a protective cover to the soil surface by contributing to soil organic matter and biological processes occurring within the soil (Fig. 3). Physical covering of the soil surface by a cover crop provides protection from the impact of rain-drop and shearing force of overland water flow. Cover crops can reduce soil compaction impact of rainfall as well as preventing the crusting and sealing of the soil surface.



Source: Kristiansen 2003

Fig. 3 Picture showing a particular cover crop (Echinacea)

Incorporation of cover crops into soil as green manure accelerates the activities of soil microorganisms and the formation of soil aggregates. During the microbial degradation of organic material, polysaccharide gums are released to serve as glue which attract soil particles together into a stable aggregate. This aggregate stability helps reduce soil erosion and improves soil structural properties related to soil aeration, water infiltration and water holding capacity (Sullivan, 2003).

3.7.4 Effects of Cover Crops in Rotation Scheme

Vegetable crop rotation is a six-year rotation. During the first six years, one year should be used for green manure to study how optimal N husbandry can be applied in any manure on a rotation system. Nitrogen supply is based entirely on legume N fixation and its measure is to reduce N losses from the soil. Vegetable rotation should include cereal crops, as problems with weeds, pests, diseases, and soil structure often become serious in very intensive vegetable rotations (Stolze et al., 2000).

The strategy of growing cover crops during dry season aims at retaining N within the growing system, and in the topsoil. Where this is not possible, the strategy of growing deep-rooted main crops or cover crops aim at recovering some of the N leached to larger soil depths.

Generally, the N management strategies have worked well, and have produced good vegetable crops without adding any external N sources to fields in rotation cycle. This assertion is based on an investigation conducted for a period of eight years experiment. This is based on the author's investigations within a period of eight years. The results of these investigations revealed that N supply for crops was not very high, but it was high enough to obtain good yields from several crops as a lot of plants such as legumes have the capability of adding nutrient back to soil when included in crop rotation.

Research results on N usage in crop rotation scheme have shown that only vegetable crops seem to have significant N limitation when compared to cabbage. The result, however, clearly shows that vegetable crops contain high amounts of nitrogen. However, result of the several investigations, were not different from other researchers.

Considering the result of investigation which include vegetables in rotation, the conclusion is that the need for the import of N containing manures to vegetable crop rotations would be strongly reduced, as it is added back to the soil. Many of the techniques used to obtain this result can, of course, be used to improve N management in other types of organic crop rotations.

3.7.5 Environmental Impacts of Cover Crops

Most research on cover crop clearly confirms that environmental impact contributes to soil fertility and improves the concentration of nitrogen cycling. Several researches also pointed out that cover crops store some major plant nutrients in their tissues. The decomposition of cover crop tissues following incorporation of the plant as green manure crop helps make the nutrients available for subsequent crop uptake. Organic acids released during decomposition of organic matter in the soil usually help to accelerate the transformation of mineral phosphorus for plant availability (Stevenson, 1986).

Cover crops transform solar energy into food for a diverse community of detritivorous arthropods, earthworms, and microorganisms. Additions of organic matter to soil stimulate microbial activities, growth and development. The diversity and abundance of living biota in a soil is a critical component in soil quality assessment.

3.7.6 Benefits of Cover Crops and Green Manures

Organic Matter and Soil Structure

The major benefit obtained from green manures is the addition of organic matter to the soil. The breakdown of organic matter by microorganisms leads

to the formation of resistance compounds. The compounds (mycelia, mucus, and slime) produced by the microorganisms assist in binding together soil particles to form granules. A well aggregated soil tills easily, is well aerated, and has high water infiltration rate. The increased levels of organic matter content greatly influence soil humus.

It is important to note that annual green manures have a negligible effect on humus levels as tillage and cultivation are practised each year. They replenish the supply of active and rapidly decomposing organic matters.

3.7.7 Soil and Water Conservation

When cover crops are planted solely for soil conservation, they provide a high percentage of ground coverage as fast as possible (Sullivan, 1991). Most grassy and non-legume cover crops, like buckwheat and rye, fulfil this need. Among legumes, hairy vetch provides the least ground cover because most of its above ground growth takes place in spring (Sullivan, 1991). However, hairy vetch offers little ground cover during erosion period. Growing a mixture of leguminous crops and grassy-type cover crops increases ground coverage and provides a specific quantity of nitrogen to some crops.

Soil conservation with the addition of cover crop provides beneficial protection to bare soil during non-crop periods. Soil cover reduces soil crusting and subsequent surface water runoff during rainy periods. It also helps to conserve soil water when used as mulch material.

3.7.8 Soil Amendments

Organic certification bodies recommend naturally mined lime products for the adjustment of soil pH to within a range of 6.0 to 7.0 (depending on crop requirements). Lime and composted manure are regarded as the most common forms of soil amendments in organic operations. Raw manure could be obtained from organic or conventional farms, provided the manure is applied at least three months prior to the harvest of agronomic crops and a minimum of four months prior to the harvest of horticultural crops. The implemented regulation provides adequate time for proper decomposition of manure and avoids bacterial contamination of produce. In order to prevent contamination of waterways, raw manure cannot be applied to frozen or snow-covered ground. It has been recommended by organic certifiers that manure should be composted prior to land application. Composting is a very good method of stabilizing manure in the soil.

Adequate moisture and temperature should be maintained for proper decomposition of the materials used in the process. Most organic farmers utilize front-end loaders or windrow turners to construct outdoor

composting systems. Other composting systems include vermi-composting (utilization of earthworms in "beds" to decompose manure and other wastes), in-vessel digesters, and anaerobic systems (Delate et al., 1999).

Soil amendments are available for organic farming. It is important that the materials are naturally based and artificial substances prohibited.

3.8 SOIL QUALITY IN ORGANIC SYSTEMS

The basic concept for organic farming is the soil health. Its main aim or focus is to ensure maximum maintenance of adequate soil fertility. Organic farmers advocate for biologically active soil containing microbial populations required for nutrient cycling to be able to support crop growth. Organic farmers support crop rotation systems in organic farming systems as nutrient like nitrogen from legumes (alfalfa and red clover) as well as carbonaceous biomass in the soil, are beneficial to soil microorganisms for survival. Naturally mined lime products can be used to adjust soil pH to 6-7 based on crop requirements. Additionally, lime, manure and composted manure are known to be the most common forms of soil amendments for organic operations. Iowa State laws in the United States of America requires that raw manure be applied to soil three months prior to harvest for agronomic crops and four months for horticultural crops, in order to allow adequate decomposition, and avoid any problems of bacterial contamination to the produce (Delate, 2005). Raw manure cannot be applied to frozen or snow-covered ground. Composting is the most preferred method of stabilizing manure. Composting is a controlled process where nitrogen-containing materials (manure, yard/kitchen waste) are mixed with carbon-containing residues (corn stalks/cobs, straw and wood chips) to produce a substance preferably in a carbon-to-nitrogen ratio (C:N) of 30 to 1 (Delate, 2005). Delate pointed out that compost mixture used should be at a temperature of about 140°F for at least three days for composting process. Other authors' investigation results also suggested that there should be adequate moisture and temperature to enhance activity of soil microorganisms for an effective composition of compost materials.

Building and maintaining soil quality is the basis for successful organic farming. However, before developing a soil management plan, emphasis should be laid on soil quality, and farmers should be acquainted with the overall philosophies, legalities, and marketing opportunities of organic agriculture.

The publication of Sivapalan et al. (1993) explained that for many years, there has been increasing public concern about the use of synthetic fertilizers and other agrochemicals on conventionally managed farms. This

has motivated the interest of organic farmers in organic agricultural management as it prohibits synthetic inputs.

Research has shown that organic horticulture and agricultural systems are associated with enhancing soil qualities and microbial populations (Sivapalan et al., 1993). Aeration, soil-water relations and access to organic matter are improved in soils under organic management. Soil characteristics can lead to heightened microbial biomass and activity, and therefore a faster rate of soil organic matter (SOM) decomposition and nutrient release (Brown et al., 2000). In addition, when organic farms include regular inputs of organic matter in their rotations, they often have a larger soil microbial biomass than conventional neighbours (Ryan, 1999).

However, an enhanced soil microbial community does not only occur under organically managed systems (Ryan, 1999). The management history of a soil can influence soil microbial biomass and activity in both conventionally and organically managed soils (Armstrong et al., 2000).

There are a number of other major indicators of soil health and quality. These include soil organic matter content, soil microorganisms, soil pH, aeration/bulk density, basal respiration, SOM, microbial biomass C and N levels, ergosterol levels, water holding capacity and N-mineralization levels. Management practices have the potential to affect indicators, health and quality of the soil.

3.9 ORGANIC MATTER CONTENT

The environmental importance of organic matter content relies on its capacity to limit physical damage and to improve nutrient availability along with biological activities. Research on organic matter concentrated on measuring the parameter of soil organic carbon content (Alfoeldi et al., 2002).

Soil organic matter or carbon (C) inputs improve soil physical properties, such as aggregate stability, and provide food, habitat, and shelter for billions of soil organisms. Increased aggregate stability, improved soil structure, and surface protection provided by crop residues. The use of manure or compost, and cover crops on farm land reduces soil erosion losses and increase water-holding capacity, soil porosity and aeration. Proper and good management of soil organic matter content helps promote soil biological activity and the healthy microbial and macrofaunal populations that are required for efficient nutrient cycling. These populations include bacteria, fungi, actinomycetes, nematodes and earthworms. The absence of these organisms in the soil will affect agricultural production.

Research conducted by Stolze et al. (2000) concluded that the conditions of organic farming has beneficial effects on the characteristics of soil organic matter due to high rate of organic carbon content in the organically farmed soils than on the conventional ones.

Fertilizers recommended for organic farming systems are based on farmyard manure, compost, green manure, rock dust, plant residues and commercial organic N-fertilizers. Consequently, there is an extensive supply of organic matter passing through aerobic decomposition processes (Alfoeldi et al., 2002). Mineralization and decomposition processes are mainly influenced by temperature, humidity and oxygen. Under humid tropical conditions, these processes run faster than the Northern conditions during the colder months. Soil type plays a role in soil mineralization process as well. Sandy soils easily dry up quickly, therefore, slow down decomposition processes. It is important for all farmers to be aware that ferralitic soils are not very fertile, but they can encourage fast decomposition and build up stable organic matter in the soil.

3.10 SOIL BIOLOGICAL ACTIVITIES/MICROORGANISMS

High level of biological activities in the soil promotes metabolism between soil and plants. In contrast to conventional farming, organic farmers depend on high and sustained supply of organic substances while the conventional farmers base their farming on synthetic elements. The aim of organic farmers is to ensure the use of organic fertilization management which is based on crop rotations with clover/grass ley, underseeds, catch crops, green and animal manure (Stolze et al., 2000). From the analysis of several research and investigations, organic farming performs better than conventional farming. This result is based on relevant parameters of several investigations.

Soil is the habitat for plants, animals and microorganisms. As plants build up organic matter, soil animals feed on them and their debris simultaneously, microbes decompose the complex organic compounds to their mineral component and to CO₂ (Alfoeldi et al., 2002). The living soil is a central part of soil fertility as activity of soil organisms promotes available elements in plant residues and organic debris entering the soil. Part of this material remains in the soil and contributes to the stabilization of humus build up. Earthworms are other important soil organisms contributing tremendously in aerating and improving the quality of soil, as they work together with fungi, bacteria and numerous other microorganisms present in the soil.

Several research results have shown that activities of microorganisms are higher in organically managed soil than in conventionally managed soil. As a consequence of the higher activities of microorganisms in organically

managed soils, nutrients are recycled faster and soil structure is improved rapidly.

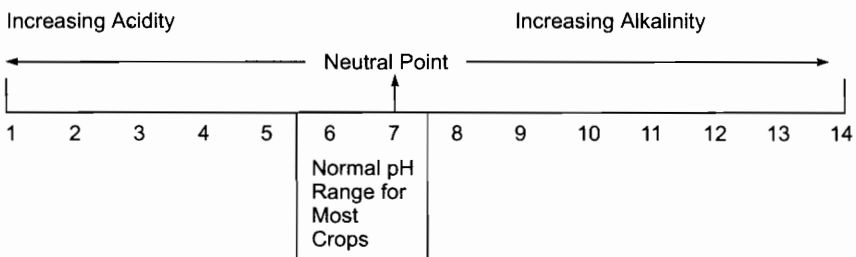
An important representative of soil fungi are mycorrhizae, which build up symbiosis between fungus and plant. The degree of mycorrhizae root colonization was found to be distinctly higher in organic plots as compared to conventional plots (Mäder et al., 2000; Smith and Read, 1997).

The process of nutrients mineralization takes place much faster on ferrallitic soils of the tropics and subtropics than on soils typical of temperate and continental zones; a high organic matter content and high biological activities are seen as the prerequisite for sustainable soil fertility. The positive impacts of organic farming on biological activity, micro-organisms and soil organic matter are very vital for soils in the tropic and subtropic regions.

3.11 SOIL pH

Soil pH is also an indicator of soil quality as it is a measure of soil acidity or alkalinity. Due to its effect on availability of nutrients and toxic elements, soil pH is considered one of the most important factors affecting soil quality and productivity (Akinyemi et al., 2005). The normal pH range for most plants is between 5.5 and 7.5. Soil acidity and alkalinity can influence both soil microbial activity and physical properties. Soil fungi are more active at a lower pH level, compared to soil microbial bacteria (McCauley et al., 2003). Effects of reduced soil microbial activity are observed through reduced plant biomass and production (Bates et al., 2002). Agricultural management systems can alter the pH of soils. Patriquin et al. (1993) suggest that conventionally managed soils are significantly lower in pH as compared to soils managed organically.

This may be due to the acidifying effects of nitrogenous fertilizers and other agrochemicals that are present in conventionally managed agricultural systems. In general, organic farming practices are less acidifying (Patriquin et al., 1993).



The requirements of plants vary widely according to the soil type. The pH of a soil can also be judged based on nature of usage and purpose. Investigations reveal that soils on which organic farming practices are carried out are less acidic. This is as a result of the nutrients made available for both cropping methods and farming systems.

3.12 AVAILABILITY OF NITROGEN TO PLANTS

An understanding of a soil's N-mineralization capacity can be of particular value because of the importance of nitrogen in crop growth and yields. To estimate the availability of soil N to plants, the factors involved in the process of organic matter degradation and the associated N turnover in the soil must be understood. Plant available N in soils originates from either artificial nitrogen fertilizers (conventional agricultural system) or mineralization of inherent and applied organic matter and plant residues (both conventional and organic agricultural systems). N-mineralization is the process whereby this organic nitrogen is converted to inorganic nitrogen via the microbial degradation of soil organic matters (SOM). N-mineralization occurs in two successive steps: (i) ammonification and (ii) nitrification. During ammonification, nitrogen within the SOM (amino acids, amino sugars, nucleic acids and animal residues) is converted to ammonia via the activities of heterotrophic fungus and chemoatotrophic bacteria. Under aerobic conditions, the ammonia is then converted to nitrate (NO_3^-) during nitrification. N-mineralization can be affected by physical, chemical, biochemical and microbiological soil parameters (Carter and Rennie, 1982; Franzleubbers et al., 1994; Ladd et al., 1994; Vavel, 1994; Omay et al., 1997; Vinten et al., 2002). Research has shown that soil structure, moisture, temperature and aeration can alter the rate of N-mineralization in the soil. These factors not only affect N-mineralization, but also other N transformation processes like denitrification, volatilization and immobilization. Nitrogen immobilization can also contribute to alterations in the mineralization processes (Rees, 1989). In order to determine the effect of mineralization process in organic and conventionally managed soils, the research experiment conducted at the University of Kassel in the Faculty of Soil Microbiology in February 2005 aimed at:

- ❖ Investigating mineralization process of nutrients in the soil
- ❖ Investigating selected biological, physical and chemical soil characteristics, in particular N-mineralization
- ❖ Examining differences between soils managed at two different sites i.e., conventionally and organically managed soil.

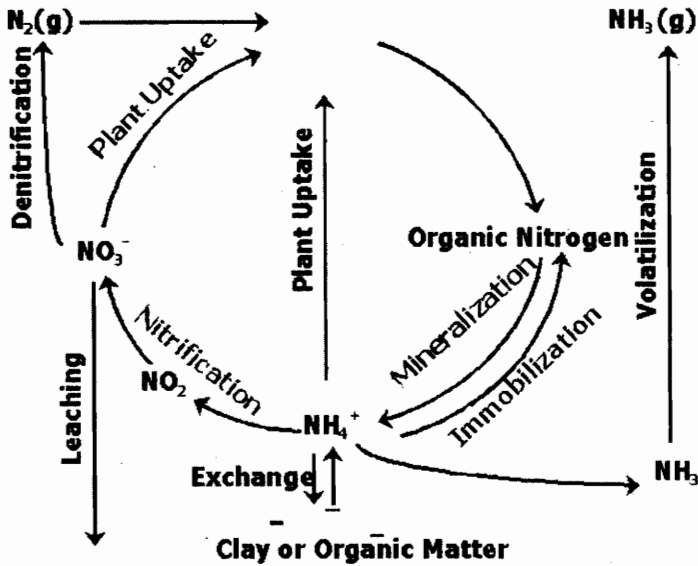


Fig. 4 Nitrogen Fixation

Nitrogen Cycle/Mineralization Process

Before the start of the experiment, the hypothesis was that when organic and conventional soils are compared, the organically managed soils would display higher microbial biomass and activity and there would be higher N-mineralization (Akinyemi et al., 2005).

3.12.1 Materials and Methods

Study Site

The study area was located near the town of Witzzenhausen in central Germany. The soils sampled were from plains flooded by the river Werra, mainly developed in the last 1200 years. The conventionally managed soils had been cultivated lately and sown with wheat. In contrast, the organically managed soils were uncultivated.

3.12.2 Soil Sampling Technique

Soil samples were taken on 14 February 2005 at a 0–15 cm depth, from organically and conventionally managed fields, at two different sites. Four core samples of 408 cm³ and a further two samples (taken as bulk samples using a vertical corer) were collected from each of the fields. All samples

were transferred to the laboratory where the bulk samples were sieved (<5 mm), pre-incubated at room temperature for two hours and stored in polyethylene bags at 4°C until the analyses commenced (Akinyemi et al., 2005).

3.12.3 General Soil Properties

Bulk density was determined using the core samples. Soil pH (tested using a soil to water ratio of 1:2.5), water holding capacity (% dry weight) and dry matter (% dry weight) were measured using bulk samples.

3.12.4 Soil Microbial Properties

The basal respiration was measured as evolved CO₂ using the titration method described by Anderson (1982). Fifty grams of moist soil were placed into 1 litre stoppered glass jars and adjusted to 50% water-holding capacity. A polypropylene vial containing 10 ml of 0.3 M NaOH was added to each of the soil samples and to three empty bottles, and the contents were incubated at 22°C for three days. After this time, fresh NaOH solution was added to each of the jars and the contents were incubated at 22°C for four days. The CO₂ evolved during each of the incubation periods was calculated from the quantity of 0.1 M HCl required to bring the NaOH solution to pH 8.3. The evolved CO₂ was calculated as follows: Evolved CO₂-C = (B-S) × M × E/DW, where B is the amount of HCl (ul) needed to titrate the NaOH in the empty bottles to pH 8.3, S is the amount of HCl (ul) needed to titrate the NaOH in the bottles containing soil to pH 8.3, M is the molarity of the HCl, E=6 (equivalent weight to express the data as carbon) and DW is the dry weight of the soil sample (g).

Microbial biomass C and biomass N were estimated using the chloroform-fumigation extraction method (Brookes et al., 1985; Vance et al., 1987). One 10 g portion was fumigated with ethanol-free CHCl₃ for 24 hours at 22°C. Following fumigant removal, the soil was extracted with 40 ml 0.5 M K₂SO₄ for 30 minutes by oscillating and shaking at 200 rev min⁻¹ and filtered through a folded filter paper (Joergensen, 1995). The non-fumigated 10 g portion was extracted similarly when fumigation commenced.

Following the removal of inorganic C by acidification, samples were combusted at 850°C in the presence of a platinum catalyzer. The organic C in the extracts was then measured as CO₂ by infrared absorption using a Dimatoc automatic analyzer. Microbial biomass C was calculated as follows: Microbial biomass C = E_c/k_{EC} , where E_c = (organic C extracted from fumigated soils) – (organic C extracted from non-fumigated soils) and k_{EC} = 0.45 (Wu et al., 1990; Joergensen, 1996).

Total N in the extracts was measured as NO_2^- by chemoluminescence detection after combustion at 850°C . Total N was again measured using a Dimatoc automatic analyzer. Microbial biomass N was calculated as follows: microbial biomass N = E_N/k_{EN} , where E_N = (total N extracted from fumigated soils) – (total N extracted from non-fumigated soils) and $k_{EN} = 0.54$ (Brookes et al., 1985; Joergensen and Mueller, 1996).

The 0.5 M K_2SO_4 extracts of non-fumigated soil samples were also used to quantitatively measure ninhydrin-reactive N at 570 nm absorbance using a spectrophotometer. The control blank was determined from L-leucine standard curve using linear regression. Microbial ninhydrin-reactive N was calculated as follows: Microbial ninhydrin-reactive N = (ninhydrin-reactive N extracted from fumigated soils) – (ninhydrin-reactive N extracted from non-fumigated soils). As the soil pH was greater than 5.0, the microbial biomass C values were calculated as follows: Biomass C = microbial ninhydrin-reactive N $\times$ 22 (Joergensen, 1996a).

Ergosterol was measured according to Djajakirana et al. (1996). Two grams of moist soil were extracted with 100 ml ethanol for 30 minutes by oscillating shaking at 200 rev min^{-1} and filtered. The filtered solution was then evaporated and the remaining ergosterol washed with methanol. A final filtration (0.45 μm) occurred before the ergosterol content was quantitatively determined by reverse-phase HPLC analysis. This occurred at 26°C using a C-18 column of $125 \times 4.6 \text{ mm}$ and a 282 nm resolution of detection.

3.12.5 Aerobic N-mineralization

Duplicate samples of 15 g moist soil were weighed into polyethylene bottles and 5 ml water added. One portion was incubated at 22°C for six days. Following incubation, the soil was extracted with 60 ml 0.0125 M CaCl_2 (4:1 extractant to soil ratio) for 30 minutes by oscillating and shaking at 200 rev min^{-1} and filtered through a folded filter paper. A non-incubated portion was extracted similarly when incubation commenced. Extractable NO_3^- -N was measured using segmented continuous flow analysis followed by spectrometric detection (540 nm) according to the manual of the manufacturer. Extractable organic N ($\mu\text{g g}^{-1}$) for both incubation periods and net N-mineralization ($\mu\text{g g}^{-1}\text{d}^{-1}$) were calculated as follows:

$$\text{Extractable } \text{NO}_3^- \text{-N} = \frac{(A-B) \times (C \times SW)}{(DW - SW)}$$

$A = \text{NO}_3^- \text{-N of the sample}$
 $B = \text{NO}_3^- \text{-N of the blank}$
 $C = \text{Vol extractant (ml)}$

Calculation of net N-min: $SW = \text{Total amount of water in soil sample (ml)}$

$$N = \frac{\text{Extractable } NO_3^- - N}{\text{Days incubated}} \quad DW = \text{Total weight of moist soil sample (g)}$$

3.12.6 Statistical Analysis

The results presented in the tables and graphs are arithmetic means. The significance of variation between the different sites and management practices was tested by simple analysis of variance (ANOVA) and analysis of covariance (ANCOVA). All statistical evaluations were performed using the StatView 5.0 program (SAS Inc.).

3.12.7 Results

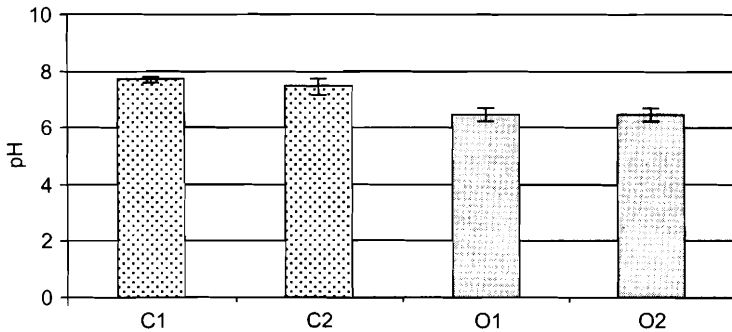
Measured parameters included pH, bulk density, basal respiration, C_{mik}, N_{mik}, dry matter, ergosterol, respiratory quotient, water holding capacity, and aerobic N-mineralization. As indicated in the table below, neither field nor soil management practice was found to significantly affected most of the parameters.

Table 2 Effects of: (1) soil management practices, and (2) fields, on the measured soil characteristics (NSD = no significant difference)

	<i>Management Practice Effect</i>	<i>Field Effect</i>
pH (unit)	Significantly higher in conventionally managed soil ($p < 0.0001$)	NSD ($p = 0.4630$)
Bulk density (g cm^{-3})	NSD ($p = 0.1743$)	NSD ($p = 0.7032$)
Basal respiration ($\mu\text{g g}^{-1}\text{d}^{-1}$ soil)	NSD ($p = 0.6433$)	NSD ($p = 0.8225$)
C _{mik} ($\mu\text{g g}^{-1}$ soil)	NSD ($p = 0.9958$)	NSD ($p = 0.3745$)
N _{mik} ($\mu\text{g g}^{-1}$ soil)	NSD ($p = 0.8946$)	NSD ($p = 0.2436$)
Dry matter (% soil weight)	NSD ($p = 0.8338$)	NSD ($p = 0.7798$)
Ergosterol ($\mu\text{g g}^{-1}$ soil dw)	NSD ($p = 0.6539$)	NSD ($p = 0.8431$)
Respiratory quotient	NSD ($p = 0.2880$)	NSD ($p = 0.7564$)
Water-holding capacity (% soil weight)	NSD ($p = 0.6382$)	NSD ($p = 0.6382$)
Aerobic N-mineralization ($\mu\text{g g}^{-1}$ soil)	NSD ($p = 0.1152$)	NSD ($p = 0.3256$)

Source: Akinyemi et al., 2005

It was found that the soil pH was impacted by the soil management practice, with the two conventionally managed soils exhibiting higher pHs when compared to the two organically managed soils ($p < 0.0001$). This difference was approximately one pH unit. In contrast, there was no significant difference ($p = 0.4630$) in soil pH between Field 1 and Field 2 (Fig. 5).

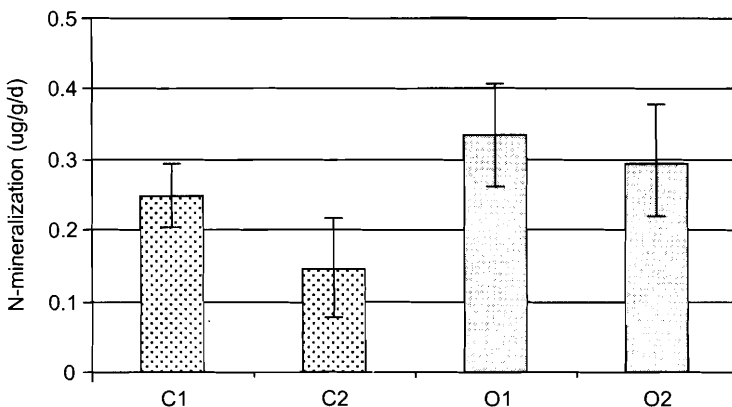


Source: Akinyemi et al., 2005

Fig. 5 Effect of (1) soil management practices and (2) fields on pH of soil

As indicated in the above table, there was no significant effect of soil management practices or fields on the level of N-mineralization in the soil. Figure 6 demonstrates the level of N-mineralization in the soil from Fields 1 and 2 that have been either conventionally or organically managed. Standard error bars displayed on this graph demonstrate highly variable results.

The effect of covariates on N-mineralization was also analyzed. There were no significant relationship between N-mineralization and bulk density ($p = 0.5912$), basal respiration ($p = 0.5956$), Cmik ($p = 0.090$), dry matter ($p = 0.3261$), respiratory quotient ($p = 0.9241$), water-holding capacity ($p = 0.7287$), Nmik ($p = 0.7080$), ergosterol ($p = 0.8662$) or pH levels ($p = 0.7948$). Therefore, there were no significant relationship between any of the measured soil characteristics and the level of N-mineralization in soil.



Source: Akinyemi et al., 2005

Fig. 6 Effect of (1) soil management practices, and (2) fields on N-mineralization in soil

3.12.8 Discussion

(a) Biological Soil Properties

The results indicate that the measured soil biological properties were independent of field and management practice. However, the results may have been undermined by the high degree of variation between the results of others. This variation may have been due to differences in soil sampling and handling techniques. For example, there may have been differences in the sampling depth and the amount of temperature changes and/or organic matter content in the sample. Compaction or incomplete filling of the core during sampling may also have occurred, which would have skewed the bulk density measurements. In addition, lack of adequate replication may have made it difficult to statistically distinguish between real differences and analytical error.

The results were in the range of those previously reported in the literature. The basal respiration, Cmik (Dimatec), ergosterol and N-mineralization values fell within the ranges obtained by Chander et al. (2001), Wichern et al. (2003) and Wichern et al. (2004). The results for Nmik (Dimatec) were a little higher than recorded by Wichern et al. (2004), but are not extreme. This comparison implies that the results from the experiment were realistic and sensible. A direct comparison of the results obtained here and those reported in the literature is shown in Table 3.

In contrast to this findings, Sivapalan et al. (1993) found that there were generally higher quantities of microorganisms in vegetable gardens that were converted to organic, when compared to those that had remained under conventional management. The increased microbial biomass appears

Table 3 Comparison of results of microbial biomass and activity, with that of literature

	<i>Basal Respiration [$\mu\text{g CO}_2\text{-C h}^{-1}$]</i>	<i>Cmik (Dimatec) [$\mu\text{g g}^{-1}\text{ soil}$]</i>	<i>Nmik (Dimatec) [$\mu\text{g g}^{-1}\text{ soil}$]</i>	<i>Ergosterol [$\mu\text{g g}^{-1}\text{ soil}$]</i>	<i>N-minerali- zation [$\mu\text{g g}^{-1}\text{ d}^{-1}$]</i>
Akinyemi et al., 2005	0.280 – 2.800	158.400 – 384.900	21.200 – 67.100	0.230 – 0.570	0.200 – 0.310
Chander et al., 2001	0.600 – 3.360	168 – 4496		0.420 –14.88	
Wichern et al., 2003	0.075 – 0.410	106 – 765		0.200 – 2.890	0.046 – 0.320
Wichern et al., 2004	0.036 – 0.250	65 – 296	10 – 39		0.523 – 0.780

to be due to higher levels of organic matter in the organic system. Sivapalan et al. (1993) also found that vegetable gardens which had previously been used as pastures for 10 years, had higher levels of microbes than those that had been planted with vegetables for the same period. In addition to this, vegetable gardens treated with compost had higher levels of microorganisms than those not treated with compost. This is not surprising considering the importance of organic matter for microbial growth and survival.

Jensen et al. (2000) used a case study to compare ergosterol levels in soil from differing farming systems—organic (plants only), conventional (plants only) and conventional (including animals)—on a sandy loam in New Zealand. They found no significant difference between ergosterol levels in the conventional and organic systems. This supported the results of our findings, as this experiment also did not find significant differences in the ergosterol levels between the conventionally and organically managed soils. However, Jensen et al. (2000) also found that there was significantly less ergosterol in the conventional plant farm soil compared to the soil sampled from conventional plant farms that included animal husbandry. The ergosterol content was correlated with the frequency of grass and legume leys, the input of animal manure, total C and frequency of ploughing. In addition, Jensen et al. (2000) found that ergosterol levels in some soils varied greatly within a few centimeters suggesting that a large numbers of samples are needed to detect differences between paddock management in a case study situation. These results highlight the importance of farming practices on ergosterol levels and suggest that there is more at play than simply the organic/conventional status of the soil.

The hypothesis of this investigation is that N-mineralization would be higher under organic management due to higher microbial biomass and activity, but was not supported by data (Akinyemi et al., 2005). Research from the Iowa State University found 8% increase in potential N-mineralization under organic management compared to conventional management. The results of this experiment did not support or oppose these findings. Although the study indicated that N-mineralization tended to be higher under organic management, this difference was not significant. In addition, this tendency may have been influenced by recent soil disturbances in the conventional systems. It is likely that some N-mineralization had already occurred in these soils due to the disruption of macro-aggregates which protected the SOM. The lack of significance in the results may again be explained by the lack of replication and high variability between authors. In addition, the results may not be statistically significant because of the modified analysis method used. The N-mineralization

analysis method normally includes two periods of incubation of 14 days each. However, due to time constraints, a single incubation period of only six days was used. This short incubation period may not have allowed the complete release of nitrogen bound to SOM. This, in turn, may have led to be lower than expected measurements of N-mineralization.

(b) Physical and Chemical Soil Properties

The soils studied had no major restrictions on plant growth or microbial activities. The bulk density values indicated that the soil was not compacted, the water-holding capacity was in a range expected from a sandy clay loam, and the pH values were in the range suitable for healthy plant growth and microbial activity. *Conventional farming has higher synthetic inputs which leads to soil acidification.* The significant difference in pH between the conventional and organically managed soils is not consistent with this process of acidification. Increased product removal from conventional farms due to the higher yields may also result in acidification of soil. The lower pH in the organically managed soils may be due to increased levels of SOM, which may slightly acidify the soil. The addition of manure fertilizers may also have acidifying effects; however additional information is required about past management practices in the fields before conclusions can be drawn. The results of this experiment differed from those obtained by Brown et al. (2000). Both studies found no significant difference between the pH of soils under organic and conventional management. Ammonia fertilizers could displace exchangeable Ca^{2+} from soil colloids. However, conventional management of soil using ammonia fertilizers could lead to a reduction in soil pH. The results of this studies are incomplete in contrast to these findings.

3.12.9 Conclusion

The experience indicated that the number of people carrying out soil microbial analysis techniques should be minimized to reduce sampling and handling variability. It also suggests that there should be sufficient replication of treatments to ensure optimal validity of results. Increased replication also allows for accurate measurement of significant differences between management practices. When comparing fields in a case study, large numbers of samples may be needed to account for field variability. The lack of significantly different results in this experiment may be due to both experimental/handling error and the lack of replication.

From the results of our experiments, no firm conclusions can be drawn or comparisons made regarding the effects of organic and conventional management practices on soil microbial properties and N-mineralization.

However, the results do suggest that the pH of soil can be reduced slightly under organic situations, perhaps due to manure inputs and SOM build up.

3.13 FACTORS AFFECTING SOIL FERTILITY

(a) Soil Erosion

Soil erosion can be a significant catalyst that aids soil degradation all over the world. The loss of fertile top soil by erosion results in lower crop yield. The comparison made by Reganold et al. (1987) in a long-term experiment showed that there was a 16 cm thicker topsoil depth on the organically managed plot as a result of lower erosion. This was probably due to inclusion of green manure legume crop in the third year of rotation and fewer tillage operations on the organic field (Alfoeldi et al., 2002). In a trial, long-term effects of organic (since 1948) and conventional farming on selected properties of the same soil had been compared in farms near Spokane in Washington, USA. The organically farmed soil did not only have thicker topsoil, but also had significantly higher organic matter content and less soil erosion than the conventionally farmed soil. The authors, therefore, concluded that the organic farming system was more effective than the conventional farming system in reducing soil erosion and in maintaining soil productivity (Alfoeldi et al., 2002).

In general, organic soil management techniques like organic fertilization; mulching and cover cropping improve soil structure and, therefore, increase the water infiltration and retention capacity. It also reduces the risk of erosion on the farm. It is, however, recommended that farmers implement good management techniques in order to have a good quality of porous feralitic soil in the tropics and sub-tropics. The effective management will, no doubt, reduce soil erosion risk as a consequence of frequent heavy rainfall.

Organic farming can successfully counter erosion, while in conventional farming in the tropics, flat soil gets eroded due to the use of herbicides and the lack of soil cover. In organic farming, a **permanently covered soil** is an intrinsic part of the system (Alfoeldi et al., 2002).

(b) Desertification

Degradation of dry lands is referred to as desertification. Desertification occurs due to over-cultivation, over-grazing and deforestation, and may lead to soil exhaustion and erosion. Desertification diminishes soil productivity, reduces food production, robs the land of its vegetative cover, and leads to negative impacts in the areas not directly affected by its symptoms. For example, floods, soil salinization, deterioration of water quality, and silting of rivers, streams and reservoirs.

Organic farming provides appropriate solutions to the problems associated with desertification. Organic farming techniques bear potentials to improve soil fertility, soil structure and moisture retention capacity. Relevant techniques used in organic farming to protect the soil include composting, mulching, use of cover crops, intercropping, and use of supplemental organic fertilizers (like compost, farmyard manure, green manure and mulch). The use of endemic species that are more adapted to climate stress, as well as water preserving and agro-forestry techniques, will help prevent desertification.

Organically managed soils have a high potential to counter soil degradation, as they are more resilient to both water stress and nutrient loss. Organic farmers feed their soils with organic fertilizers, and thus enhance degraded and problematic soils (Alfoeldi et al., 2002).

With a high level of organic matter and a permanent soil cover, water and nutrient retention capacity increases, it provides a good feeding zone for microorganisms, and creates a stable soil structure. Due to the resulting high moisture retention capacity, the amount of water needed for irrigation can be reduced substantially.

So far there is little scientific evidence demonstrating organic farming's potential for combating desertification. Organic farming can help bring degraded lands back to fertility. An organic farmer in Egypt cultivating 70 hectares desert near Cairo was found using organic and biodynamic agricultural methods (composting, mulching and cover cropping), consequently the desert sands were converted into fertile soil, supporting livestock and bees. The method used by the Egyptian farmer motivated Sekem in the early 1990s and he started applying biodynamic methods to cotton. The success in cotton pest control (by pheromones) raised the interest of Egyptian authorities in biological control. Today, nearly 80% of Egypt's cotton cultivators apply biological pest control, and the Ministry of Agriculture has placed a ban on aerial sprays of synthetic pesticides on cotton farms, with a view to promote biological control. The organic cotton producers in Egypt currently use organic fertilization such as compost, wood ash, rock phosphate and clover-onion rotations, to produce crops.

(c) Environmental Factors

Crops and animal distributions are greatly affected by environmental factors such as climatic conditions. These are natural factors that influence:

- ❖ Nature of vegetation
- ❖ Soil characteristics
- ❖ Type of farming system
- ❖ Type of crops and animals raised

The climatic factors influencing agricultural production include:

- ❖ Temperature
- ❖ Rainfall
- ❖ Wind
- ❖ Humidity
- ❖ Light

(d) Influence of Climatic Change on Agricultural Development

It is recognized worldwide that agriculture is the economic mainstay in most African countries and contributes about 20–30% to the countries GDP, especially in Sub-Saharan Africa, and 55% of the total value is exported. From statistics, 70% of African poor people live in rural areas. The yield of crops and changes in productivity due to climatic change vary considerably across regions of Africa. In the tropics and subtropics, where some crops are tolerant to maximum temperature and where dryland is found, non-irrigated agriculture dominates. In these regions, yields are likely to decrease with even small increases in atmospheric temperature. Overall agricultural productivity in Africa could decrease during the next century leading to hunger and malnutrition in vulnerable areas, especially in drought-prone regions of the continent.

It has also been reviewed by researchers that steady warming of the earth's surface temperature has enormous implications on agriculture, and a small increase in temperature means decrease in agricultural production.

Impact of climatic changes on the availability of water in Sub-Saharan Africa is of major concern to the scientists. It is currently recorded that a population of about about 1.7 billion in developing countries are living in areas where water resources are scarce. This number is expected to increase to about 5.4 billion over the next 25 years. In general, rainfall is projected to increase slightly over much of the continent, but a decline in rainfall is projected for southern Africa, especially in winter. These changes in rainfall and higher temperatures are projected to exacerbate water shortages in southern Africa and in African countries around the Mediterranean Sea. The predominance of rain-fed subsistence agriculture and, across southern Africa, high dependence on water-demanding maize, means that food security for most of the continent is inextricably linked to the amount of rainfall. In dryland regions, crop and livestock production is also extremely susceptible to seasonal rainfall variability. Increased droughts result in climatic change and could seriously impact food availability just like the case of Africa and southern Africa which occurs during the 1980s and 1990s.

Assessing the impacts of climatic change on agriculture is a vital task in both developed and developing countries, the influence of climate on crops

and livestock persists despite irrigation, improved plant and animal hybrids and the growing use of chemical fertilizers (Rosenzweig et al., 1992). The continued dependence of agricultural production on light, heat, water and other climatic factors, the dependence of much of the world's population on agricultural activities, and the significant magnitude and rapid rates of possible climatic changes, all combine to create the need for a comprehensive consideration of the potential impacts of climate on global agriculture (Rosenzweig et al., 1992).

The projected climatic changes for the temperate and tropical areas differ in climate models project, there is a greater magnitude of temperature increase in temperate regions than in tropical regions. The projections of changes in the hydrological cycle are almost similar, but rather uncertain, showing a mixed picture of regional precipitation increases and decreases in both areas (Rosenzweig et al., 1992).

(e) Influence of Climatic Change on Crop Production

Climate impacts on agriculture lie on biophysical sciences. The rates of most biophysical processes are highly dependent on climate variables like radiation, temperature, and moisture. The rates of plant photosynthesis depend on the amount of photosynthetic active radiation and the levels of atmospheric carbon dioxide (CO_2). Temperature plays an important role in plant progression through various phenological stages towards maturity. The accumulation of biomass is facilitated by the availability of moisture and nutrients to a growing crop.

Several studies have shown that the impact of climatic changes varies on agriculture (Thompson, 1975; World Meteorological Organization, 1979). The study clearly demonstrates the sensitivity of both temperate and tropical agricultural systems to climatic variations and changes. In temperate regions, the impact of climate variability, particularly drought, on yields of grains, has been the main concern for scientists, as it adversely affects world food security. In the tropics, drought impacts on agriculture and resulting food shortages have been widely studied, especially when associated with the failure of the monsoon in Asia or rains in Sudano-Sahelian Africa. In the temperate regions, climatic variations are associated with economic disruptions; in the tropics, droughts bring famine and widespread social unrest (Pierce, 1990).

(f) Other Factors Affecting Soil Fertility

- ❖ **Biotic Factors:** This examines the effects of interaction of other organisms with plants and animals. It overviews the effects of pests and diseases on crops, predators, parasites and other microorganisms.

- ❖ **Edaphic Factors:** This looks at soil conditions and its influence on agricultural production. It overviews the soil pH, soil structure and soil texture

3.14 CARBON SEQUESTRATION IN FARMING SYSTEM

Recently, some world governments promoted the use of soil carbon sequestration (storage) to help mitigate elevated levels of atmospheric CO₂ caused by burning fossil fuels and other sources of industrial pollution in the environment.

Application of crop rotation scheme, effective manure management, and green manuring are required for effective and efficient organic farming in all management practices that can enhance carbon storage in the soils though tillage practices help increase CO₂ emissions. Farmers should note this important aspect evaluating the tradeoffs associated with organic systems and carbon sequestration.

3.15 ORGANIC AGRICULTURE/MICROCLIMATES

Organic agriculture can create suitable microclimates in dry areas for the purpose of production. In Kenya, the International Centre for Research in Agroforestry (ICRAF) have established organic farming projects to eradicate drought condition. Agro-forestry is one of the best uses of agro-biodiversity that also generates multiple benefits, including erosion control and moisture retention. In Tanzania, the Chagga home gardens on the slopes of Mount Kilimanjaro, where certified organic coffee is produced, display an excellent example of agroforestry (Alfoeldi et al., 2002). The system used includes a diversity of cash and subsistence crops (e.g., bananas, coffee, yams, and beans) as well as livestock.

Cattle and pigs are kept in stables (zero grazing) while the manure is recycled to provide fertility. The home gardens were designed to maximize diversity.

3.16 GROUND AND SURFACE WATER

It was pointed out by Alfoeldi et al. (2002) that the detrimental effects of intensive agriculture on ground and surface water are largely due to erosion, nitrate and pesticide pollution. Other literature also explained that the most important threats to water quality caused by agriculture are high organic fertilization levels together with high stocking rates. Frequent and excess application of mineral N-fertilizers can contaminate soil water as well. With well tillage practices and the use of cover crops and crop rotation scheme,

the effects of soil water contamination can be reduced. In this case, the impact of organic farming on water quality can be evaluated by analyzing the parameters of pesticides and nitrate leaching.

Since organic farming does not involve use of synthetic pesticides and other artificial or synthetic elements, there is no risk of ground and surface water pollution through synthetic elements. There is also a lower rate of nitrate leaching in organic farming due to ban of mineral N-fertilizers and lower livestock density. The constraints set up by the organic farming standards lead to this situation. The opportunity costs (costs to produce nitrogen on-farm) of 1 kg nitrogen on organic farms can amount from seven to sixteen times the costs of mineral N-fertilizers (Stolze et al., 2000). In contrast to conventional farms, where manure and slurry are often a waste problem, organic farmers are forced to develop efficient nitrogen management strategies like intercropping, catch cropping, optimal ploughing of leguminous crops or limiting the use of liquid manure to avoid nitrogen losses (Alfoeldi et al., 2002).

Effects and Consequences of Agricultural Chemicals on Soil

4

Chapter

Currently, governments of different countries fund large numbers of researchers studying the side-effects of toxic and undesirable chemicals, and solutions to the symptoms of problems caused by chemical usage on soil, with a view to improve quality of produce. The essence of scientific studies on chemicals are to:

1. Examine the problem of agricultural chemicals on soil
2. Design ecologically sound management strategies for dealing with non-productive soils, pests and diseases
3. Evaluate crop yield in both chemical farming and non-chemical farming
4. Examine the taste of organically produced products in comparison to conventionally produced products.

In a symposium on pesticides in soil, it was stated by Audus (1970) that scientists must realize the fantastic complexity of the physical and biological structure of soil and the dynamic nature of its biological equilibria. Additionally, hundreds of papers and reviews concerning the relationships between chemicals used in agriculture, forestry and soil have publicized comments on the adverse effects of chemicals in agricultural production (Guenzi et al., 1974). Evans (1970) pointed out that "Life is on a Little Known Planet" and that a great deal has been learnt, but humans are still unable to conclude on the right methods for use in production. Needham (1932) once criticized biological scientists for not being able to implement the rightful way to achieve the best in agriculture. Medawar (1969) also mentioned that, there are plenty of analysts among modern scientists but few synthesists are known. It is felt that poor understanding of soil is closely related to lack of nutrient synthesis by plants. This has become particularly evident some years ago when a number of colleagues of the

author from the University of Kassel attempted to review the effects of chemicals on soil and its inhabitants following the steps taken by Hill, 1972; Weetman et al., 1972; Weetman and Hill, 1973; Hill et al., 1975. It was extremely difficult to compare the results of different works, partly because none of them had measured sufficient variables to draw meaningful conclusions, but more particularly because there is really no established framework for viewing the relationships in soil.

4.1 CONSEQUENCES OF CHEMICAL USAGE

One of the most prolific reviewers of studies, Dr. Clive Edwards, once analyzed the effects of agricultural chemicals on soil organisms. His conclusion was "the most usual effect of agricultural practice is to decrease the number of species of soil organisms and the few species that remain will be able to multiply rapidly until the total numbers are greater than they were originally. This statement is somehow true. However, some organisms reproduced may act as pests to crops. On the other hand, the statement is unacceptable as the reduction of soil organisms will affect nutrient turnover and aeration. Also, the time taken for the multiplication may affect certain activities expected to be carried out by a large number of soil organisms. It was pointed out by Edwards (1965) and Edwards and Thompson (1973), that the main difference from cultivation is the effects of chemicals which are expected to last longer. It was explained that ploughing or rotation of crops can only change the balance of soil fauna or flora within weeks or at most months, whereas persistent chemicals can alter them for months or years. Looking only at the beneficial effects of chemicals and ignoring the disastrous aspects will not promote agriculture in the long run. The adverse effects caused by chemicals used on soil, on both human health and environment, are fully known.

A lot of authors have focused their attention on agricultural insecticides and fertilizers. These are not the only external regulations through chemical inputs. Other chemicals used by farmers also affect and deter the activities of soil organisms directly. In fact, there is a vast array of agricultural chemicals, the effects of which are usually sublethal rather than lethal. Another common misconception is that increases in population density are good whereas decreases are bad. Thus, Harris (1969) pointed out that not all chemicals decrease the rate of soil organisms, but instead increase their activities and multiplication. He cited examples using collembola, a largely beneficial group of soil arthropods. He noted that the application of DDT changes the composition of species. Unfortunately, the role of most organisms in the soil is poorly defined to permit such analysis at the present time.

4.2 EFFECTS OF CHEMICALS ON SOIL

The continuous use of chemical inputs such as pesticides has resulted in damage to the environment causing human ill-health, negative impact on agricultural production and reducing agricultural sustainability (Pimentel et al., 1992; Pimentel and Greiner, 1997). Chemicals affect environment on farms and in neighbouring areas through disruption of beneficial insect populations and through groundwater contamination (Beck and Quigley, 2001). It has also affected the fauna and flora adversely (Pimentel and Greiner, 1997). Numerous short- and long-term human health effects have been recorded. The decimation of beneficial agricultural predators of pests has led to the proliferation of several pests and diseases (Pimentel and Greiner, 1997).

Several studies addressed the possible environmental impacts of agricultural pesticides (Liu et al., 1995; Mostaghimi et al., 1993; Ritter, 1990; Shumway and Chesser, 1994; Skinner et al., 1997). Some have also analyzed the possible reductions of pesticide use for environmental reasons (Beach and Carlson, 1993; Crowe and Mutch, 1994; Whittaker et al., 1995). Much of the concern on environmental impacts of pesticides mainly focused on contamination from the applications (Gunter and Centner, 2000). Agricultural chemicals affect non-target species such as animals and soil organisms, contaminate drinking water supplies and the atmosphere. Groundwater contamination is caused due to percolation of pesticides through soil, runoff or soil erosion, volatilization of pesticides into the atmosphere, and drift resulting from pesticide spraying. The use of chemicals in plant boosters also results in: (1) deterioration of soil friability, creating hardpans soil, (2) destruction of beneficial soil life, including earthworms, (3) altering vitamin and protein content of certain crops, (4) making certain crops more vulnerable to diseases, and (5) preventing plants from absorbing some needed minerals.

Recommendation

Chemical usage on soil as described in some literature is not only detrimental to soil organisms, but also to humans who may consume chemically produced crops and animals. Beside, chemicals have an adverse effect on the environment we live in. Scientific evidence available indicates that in most instances, the use of agricultural chemicals is inadvisable as it affects human health and destroys the natural environment in which we live in. In this case, it is advised that farmers and producers should refrain from chemical usage in crop and animal production.

4.3 DEVELOPING AND MAINTAINING FERTILE SOILS

With respect to soil fertility, it is relevant to review how soil is formed. The formation of soil requires two material inputs, rocks (the earth's crust) and dead organic matters. These are converted into soil largely through the process of decomposition.

There is certainly no shortage of rocks and dead organic matters in temperate countries as the optimum temperature for production is nearer to the annual mean temperature than the optimum temperature for decomposition. This, in fact, is the main reason why deep litter layers are found in most forests, whereas there is usually no litter layer in lowland tropical forests. The biological decomposition of organic matters is mainly carried out with the help of bacteria and fungi.

Lack of effectiveness of these organisms is affected by six factors. This is where the soil fauna play an important role because through their feeding and movement, they are continually removing the limiting factors for the microflora, particularly through their ability to distribute the spores of the latter. Thus, if certain members of the fauna are killed or reduced by agricultural chemicals, the activity of the bacteria and fungi species will decline. Increases in the population density of certain groups of soil organisms can also lead to problems through imbalance.

While detailed knowledge of these processes is currently very poor, the basic fact that by taking into account organisms in the soil and catering to their needs will contribute to the maintenance of soil fertility. The primary objective of land management is to ensure the return of organic materials taken from the land.

4.4 PREVENTING OUTBREAKS OF PESTS AND DISEASES

Pests and diseases are symptoms of poor management. Pesticides, antibiotics and drugs have generally been regarded as "magical bullets" that eliminate pests and disease problems. The act of elimination of pests and diseases is the result of trying to create a conducive atmosphere for plant growth and development. However, the use of pesticides and antibiotics to control pests and pathogens leads to the development of a long list of serious secondary problems in agricultural production. The reason is, as most pesticides are synthetic organic compounds that have no counterpart in nature, they are likely to accumulate in the environment, thereby causing serious problems to human health.

Pesticide approach predominates largely because most of the costs (e.g., environmental, human health) are not taken into account in our cost benefit analysis (Moore, 1967).

In order to treat pest problems at the causal level, it is necessary to examine in detail the relationships between agricultural practices and pest damage. This approach has been used to generate the strategies. Basic principles must be designed for each unique situation; consequently the particular strategies employed should ideally be selected by the farmer himself.

4.5 IMPLEMENTING CHANGES IN CHEMICAL APPLICATIONS

Changing from chemical to management strategies will not be easy. Modern agriculture has become dependent on chemicals just as heroin addicts have become dependent on their drugs (neither pesticides nor stimulatory drugs treat problems at the causal level). The irrational outbursts experienced on withdrawal of these two "drugs" share certain features in common; such outbursts are a measure of a loss of true freedom, the kind that is unfortunately not protected by any Bill of Rights.

Due to the addictive nature of the problem, the implementation of alternative ecological strategies will require an enormous cooperative effort involving the general public (consumers), industry and commerce (including producers), researchers (in federal and provincial governments, universities and industry), communicators (media people, educators, and extension agents) and governments (federal, provincial and local). The alternative to cooperation is to respond to the crises that will undoubtedly occur with increasing frequency. If we continue with the kinds of solutions to problems that are exemplified by the use of agricultural chemicals (Whiteside, 1977), agricultural development will improve rapidly.

4.6 ECOLOGICAL STRATEGIES FOR PEST CONTROL

(a) Selection of Plant

1. Stricter limits on plant introduction
2. More thorough quarantine procedures for introduced plant materials
3. Increase genetic diversity
4. Develop and use resistant varieties
5. Only use healthy seeds and plants, e.g., certified disease free, and from reliable dealers
6. Use varieties suited to your soil and climate
7. Use seeds inoculated with beneficial microorganisms
8. Develop and use varieties able to compete with weeds
9. Develop and use varieties able to grow in mixed culture

(b) Selection of Site

Selection of site, particularly the soil, for its ability to satisfy all the needs of plants and to avoid pest damage, requires detailed knowledge of plants, soils, and pests.

Consider:

1. Soil type, fertility, structure and drainage
2. Elevation, slope, aspect
3. Location in relation to other features of the landscape
4. Climate
5. Previous history of site, i.e., crop, tillage, chemicals, pests
6. Modify site, if necessary, to meet needs of crop

(c) Planting

1. Crop rotation
2. Mixed or companion planting
3. Management of field borders and other adjacent environments to favour natural controls, e.g., by provision of nursery or trap crops, nesting and overwintering sites
4. Plant at the best time and in the best way for the plant and the worst time and way for the pest
5. Introduce preventative pest control devices, e.g., tree bands, barriers, pheromone or other traps
6. Design size and shape of plots to discourage pests

(d) Maintenance of Site**General:**

1. Create and maintain optimum soil conditions for the plant and beneficial soil and aboveground organisms and unfavourable conditions for pests, e.g., through appropriate tillage, irrigation, drainage and application of organic and inorganic amendments and mulches; inoculation of plant and/or soil with beneficial organisms.
2. Avoid damaging the plant or stressing it with growth stimulants or toxins, e.g., unbalanced fertilizers, hormones, herbicides and pesticides
3. Practice good sanitation
4. Prune and thin where and when necessary
5. Monitor pest populations

(e) Harvesting, Distribution, Storage and End-of-Season Chores

1. Time of harvest to avoid late pest attack
2. Store only healthy, pest-free produce in optimal conditions for crops and unfavourable conditions for pests

3. Destroy crop residues and potential overwintering sites of pests
4. Manage soil overwinter to reduce pests and encourage natural controls

(f) Reasons to Opt for Organic Products

1. Organic food has a distinguished natural taste
2. Organic production reduces health risks
3. Organic farms respect water resources
4. Organic farmers build healthy soil
5. Organic farmers work in harmony with nature
6. Organic producers are leaders in innovative research
7. Organic producers strive to preserve diversity
8. Organic farming helps keep rural communities healthy
9. Organic abundance—foods and non-foods alike

(g) Nutrient Usage in Plants

Adequate and balanced supply of nutrients in the soil is very necessary for several reasons in agricultural improvement. Surplus nutrients in the soil might result in nutrient losses which may subsequently lead to water and air contamination and eutrophication of the farming environment. Nutrient deficiency is synonymous with the overexploitation of soil nutrients in the long run, consequently, this may lead to decrease in the performances, yield and quality of crops.

Research conducted by Freyer (1997) in Switzerland explained that 14% of all organic farms have an N-surplus, and only 1.5% have a P-surplus. It was further explained that most of the organic farms have a negative nitrogen and phosphorus balance. Table 4 shows the results of phosphorus

Table 4 Phosphorus and potassium balances (kg/ha) compared with organic and conventional farms

	<i>P Balance (kg/ha)</i>		<i>K Balance (kg/ha)</i>	
	<i>Organic</i>	<i>Conventional</i>	<i>Organic</i>	<i>Conventional</i>
Sweden	-12	+37	-4	+39
Netherlands				
Cash crop farm	+18	+23	+31	+25
Horticulture	+32	+60	+119	+110
Dairy farm	+8	+31	N.A.	N.A.
Germany				
Mixed farm	-4	+13	-27	+31
Dairy farm1	-2	+5	+7	+20

Source: Stolze et al. (2000) N.A. = Not available

and potassium balance in some European countries. At the end of the research, it was concluded that the phosphorus and potassium surpluses of organic farms are significantly lower than those of conventional ones (Stolze et al., 2000).

Due to negative nutrient balances as shown in the table, the question raised was that does an organic farming method cause gradual loss of soil minerals? In the first case, the proportion of soluble nutrient fractions is lower on organic managed soils. On the other hand, Mäder et al. (2000) found no decrease in organic yields as an indicator for nutrient deficiency on farms that are managed organically for more than 30 years. Oberson et al., (2000) pointed out that higher biological activity and higher mycorrhizal root colonization counteract nutrient deficiency. He also noted that the aim of organic farmers is to increase the supply of nutrients through increased biological activity.

Disease and nematode management in organic farming systems is the reliance on the inherent equilibrium in nature. Insect pests have natural enemies that keep their numbers in check. The natural enemies category are insect predators (insects that consume part or all of pest insects), parasitoids (insects that use other insects to produce their offspring, thereby killing the pest insect in the process) Delate (2005), and pathogens (diseases that kill or decrease the growth rate of insect pests). The predatory insects in organic farms include lady beetles, lacewings, and mites. The parasitic insects include wasps and flies that lay eggs in or on pest insects like larvae or caterpillars.

The natural enemies of pests exist naturally on farms. They can be bought from commercial insectaries and released seasonally. The commercial preparations of natural insect pathogens like *Bacillus thuringiensis* (Bt), are used to manage pestiferous larvae, like corn borers. Botanical insecticides, such as neem, pyrethrin and ryania, are recommended in organic production to control pests.

Neem is a relatively new product on the market. It is derived from the neem tree that grows in arid tropical regions. Extracts from the neem tree have been reported to control over 200 types of insects, mites, and nematodes. The neem spray solution should not be exposed to sunlight and must be prepared with water having a temperature between 50 and 90°F. The solution is effective for only 8 hours after mixing. Neem is most effective under humid conditions or when the insect and plants are damp. It has a low toxicity to mammals (Evans, 2000).

Pyrethrin is a fast acting contact poison derived from the pyrethrum daisy. It is very toxic to cold-blooded animals. Some people and most cats have allergic reactions to it. Pyrethrin is effective on most insects, but does not

control mites. It rapidly breaks down in sunlight, air and water (Evans 2000).

Ryania is a slow acting stomach poison. It has a longer residual than most botanicals. Toxicity to mammals is moderate (Evans 2000).

In organic farming, physical and cultural methods can be used to prevent pest infestations. Physical methods include the use of row covers for protection against insects, cabbage butterflies and aphids. Cultural methods involve sanitation, which includes the elimination of all infested plant material at the end of seasons and the use of resistant varieties.

5.1 INSECT PEST CONTROL

Three basic approaches to biological control are relevant for an area with the IPM (International Pests Management) programme. IPM approaches include: (1) classical (importation), the introduction of natural enemies from the region of origin of an exotic pest for the permanent suppression of the pest in a new target region; (2) augmentation (the periodic release of insectary-reared natural enemies to either inoculate into a crop for season-long suppression of a target pest, or to inundate the crop with natural enemies during each generation of the pest for immediate but short-lived suppression); and (3) conservation (the modification of crop production practices to prevent the destruction of resident natural enemies and to enhance the activity of natural enemies in the target crop).

5.1.1 Classical Biological Control

Biological control of agricultural pests has a history of more than one thousand years (Hawkins and Cornell, 2000). Traditionally, most attempts at biological control have used the introduction of natural enemies against exotic pests, but additional methods have now been developed. These include periodic release of mass-produced agents (e.g., *Encarsia formosa* and *Phytoseiulus persimilis*) and augmentation of their effectiveness (Hawkins and Cornell, 2000).

Chemical control does not require much information compared to that of biology and the ecology of pests (Collier and Steenwyk, 2004). Reduction of pests on fields is easily achieved, temporarily by killing the maximum possible individual pest population. Biological control is not so simple because it affects the interspecific relationships of organisms in the field (Hawkins and Cornell, 2000). The mechanisms of biological pest control are consequently very complicated. The effectiveness may be very sensitive to environmental factors. To increase the efficiency and the reliability of

biological control, more science-based technology should be used (Hawkins and Cornell, 2000). Biological control has been applied experimentally in a large number of pest systems (Ridgway and Vinson, 1977; Stinner, 1977; King et al., 1985; Parella et al., 1992).

5.1.2 Augmentative Biological Controls

The use of "augmentative" biological control for the control of arthropod pests has been recognized for many years (Doutt and Hagen, 1949; DeBach, 1964; Ridgway and Vinson, 1977; Stinner, 1977; King et al., 1985, Parella et al., 1992).

The augmentation of natural enemies has proved an effective tactic in pest management in several crops. An experiment carried out indicates that inoculative releases of egg-larval parasitoid and quadridentatus could elevate the level of parasitism. Parasitoid augmentation shows considerable promise for integration with other selective control tactics such as mating disruption, sterile insect release, or selective pesticides.

5.1.3 Use of Crops

Cover crops have been shown to have both beneficial and detrimental effects on crop pests. Incorporating green manure as cover crops has been shown to reduce incidence of a wide array of plant pathogens (Mangan et al., 1991). Rothrock and Kendig (1991) pointed out that hairy vetch cover crops reduced incidence of black root rot disease on cotton (*Thielaviopsis basicola*).

Ingham (1993) demonstrated in his publication that cultivars of rapeseed and Sudan grass suppress root-knot nematode (*Meloidogyne chitwoodi*) in potatoes. It has been observed that the integration of cover crops and non-fumigant nematicide, Mocap, reduces tuber damage. Mangan et al. (1991) explained that substantial control of weed growth and development was provided by rye and vetch cover crop mulches, as well as several cereal cultivars.

Cover crops influence arthropod pest abundance in several ways like serving as a host for alternative prey for beneficial arthropods, providing favourable environment for common predators like carabid beetles, interfering with the host-finding abilities of pest species and serving as a trap crop to distract pests from the primary crop.

5.1.4 Conservation of Biological Controls

The integration of parasitism into area wide codling moth management necessitates a clear understanding of the interaction of management tactics

and the selection of complementary treatments. The general objective of reducing or eliminating the use of broad-spectrum pesticides against codling moth in pome fruit crops in the western US created a more hospitable environment for natural enemies and constituted the most important element of the conservation of imported and augmented parasitoids.

Another important component of biological control conservation is the provision of adequate food sources and resting sites for the adult natural enemies (Powell, 1986; Altieri et al., 1993; Evans, 1993). Many adult parasitoids and predators feed on honeydew, nectar, and plant exudates, while adult predators often feed on pollen or fungal deposits to obtain sufficient food for the maturation of eggs. These food sources, together with a more humid microclimate, greater shade, and resting sites, should be introduced into pome fruit crops through orchard floor management. The presence of wild flowers in apple orchards has been shown to increase the abundance of parasitoids and significantly enhances the control of San Jose scale, woolly apple aphid, and codling moth.

5.1.5 Beneficial Organisms

Beneficial insects are divided into two groups, parasites and predators. A predator is an organism which during its development, consumes more than one prey individual. Parasites can be further divided into parasites and parasitoids. A parasite is an organism that lives in or on the body of its host without killing the host, but usually debilitating the host to some extent. A parasitoid, on the other hand, is an organism which during its development, lives in or on the body of a single host individual, eventually killing that individual. In reality, most "parasites" are actually beneficial. Many pest insects are also susceptible to entomopathogens which are simply disease-causing organisms such as bacteria, viruses, protozoan or fungi.

5.1.6 Parasitism

Parasitic wasps are an extremely important and a large group of beneficial insects with about 16,000 species found in North America. These wasps are very small, generally less than 1/8 inch long, and usually not noticed.

Some wasp larvae feed and pupate inside the host (endoparasites) and the emerging wasp leaves a small circular hole on the body of the host as evidence of parasitism. Many harmful insects such as aphids, whiteflies, scales, leaf miners and caterpillars are also parasites. The emergence holes made by aphids and scales on the body of the host are very obvious.

5.1.7 Predators

Assassin bugs are generally black or brown, but some are brightly coloured, and $\frac{1}{2}$ to one inch in length. The head is elongate with a short curved beak. Nymphs are just as effective in controlling pests as adults. There are about 3,000 species in the world and more than 160 North American species. All species are predaceous and attack a wide variety of insects. They inflict a painful bite if handled.

Another example of an assassin bug is the wheel bug. It gets its name from the semicircular crest on the thorax that resembles a cogwheel. It also inflicts a painful bite.

Ambush bugs are closely related to assassin bugs and are $\frac{1}{4}$ to $\frac{1}{2}$ inch long. Their front legs are very thick for grasping their prey. They wait on flowers where they are camouflaged by their matching body colour. They feed primarily on wasps and flies.

5.1.8 Lacewings

Green lacewings are common insects, found on weeds, cultivated row crops and shrubs. They are greenish with copper-coloured eyes and about $\frac{3}{4}$ inch in length. The wings are transparent with many veins, which give them the name lacewings. About 87 species are found in North America. They are relatively slow flyers. The adults may be predaceous or feed on pollen.

Lacewing eggs are deposited at the end of long hair-like stalks that are attached to the leaf. The female lacewing deposits a small amount of stalk fluid to the leaf and the abdomen is uplifted, resulting in a viscous upright thread. An egg is deposited at the end of the thread. The thread hardens rapidly, forming a delicate stalk. This prevents the larvae from cannibalizing each other.

Lacewings are elongate and have large sickle-shaped mandibles. They are active, but sluggish and soft-bodied, with tubercles (raised bumps) and long setae (hair). They are commonly called aphid lions and feed on aphids, other small insects and eggs. Some species of brown lacewing larvae cover themselves with the skins of their victims and other debris.

5.1.9 Lady Beetles

Lady beetles are among the most beneficial insects. There are approximately 5,000 species worldwide with about 475 species found in North America. Only two of the 475 species in this family (Coccinellidae) are harmful and feed on plants. These are the Mexican bean beetle and the squash beetle.

Both the adults and larvae of lady beetles are predaceous on aphids, immature scale insects, mealy bugs, mites and other soft-bodied insect pests as well as insect eggs. Adult lady beetles are oval shaped, and generally orange or reddish in colour with black markings. Lady beetles are usually about $\frac{1}{4}$ inch long, but some range from $\frac{1}{16}$ to $\frac{1}{2}$ inch. The expanded thorax conceals the head from above.

Studies have found that 200–500 aphids are consumed during the larval stage, depending on the species. The adults are usually even more voracious.

5.1.10 Damsel Bugs

These are small insects that range from $\frac{1}{8}$ to $\frac{3}{8}$ inch long, yellowish to brownish in colour with prominent eyes. They are vital predators, feeding on a wide variety of insects including aphids and caterpillars.

5.1.11 Insects Attractants and Traps

Many chemical and visual lures attract insects and can be used to monitor or directly reduce insect populations on agricultural fields. Attractants can be used in such a way so that they do not cause injury to other animals or humans and do not result in residues on foods or feed. They are suitable to environmental sound pest management programme.

The use of attractants and traps in an effective form requires technical know-how of basic biological principles.

5.1.12 Chemical Attractants

Chemicals that act as attractants or carry other messages across distances are volatile compounds. When released into the air, they can be detected by certain insects within a few inches to hundreds of yards away. Insects use many different semiochemicals—chemicals that convey messages between organisms. Semiochemicals are similar to tastes or smells perceived by humans. The use of these chemicals by insects is characterized by a high degree of sensitivity and specificity. Semiochemicals may carry messages either within or between species.

5.1.13 Pheromones

Problems related with the use of pesticides have created an increased interest and need for ecological approaches to insect control (Farrell et al., 1992). The use of pheromones for mating disruption of insect pests is a technique that can potentially lead to a large decrease in the amount of synthetic pesticides that are used by farmers (Atterholt et al., 1999). The

difficulty in developing controlled release formulations that could be sprayed on field or orchard crops and release pheromones at a constant rate over an extended period of time has been one factor limiting the widespread use of mating disruption as a pest control method.

Paraffin wax and aqueous paraffin emulsions can be used as controlled release carriers for insect sex pheromones for mating disruption of orchard pests. Paraffin can be applied at ambient temperature as an aqueous emulsion, it adheres to the tree bark or foliage and releases pheromone for an extended period of time (Atterholt et al., 1999).

These are semiochemicals that are produced and received by members of the same species. A wide range of behaviour and biological processes are influenced by pheromones. In pest management, compounds that attract a mate-sex pheromones or aggregation pheromones, are used for pest control. Other pheromones regulate caste or reproductive development in social insects like honeybees and termites. Signal alarm and mark trails serve other functions.

Practical use of pheromones or feeding attractants for pest management usually requires specific active chemicals to isolate, identify and produce synthetically. Synthetic attractants, e.g., usually copies of sex or aggregation pheromones or feeding attractants, are used to lure in traps and monitor pest population.

The use of traps has been demonstrated in widely publicized efforts to detect and eradicate exotic pests like gypsy and the Mediterranean fruit fly, whenever infestations are detected in new areas.

Since pheromone traps are very effective for catching certain insects, numerous traps placed in a pest's environment can sometimes remove enough insects to substantially reduce the local population and limit the damage it causes. Aggregation pheromones attract both male and female beetles or species-specific sex pheromones that attract male moths. While aggregation pheromones are used to attract adult beetles of both sexes, traps may reduce reproduction by capturing adults before they lay eggs, and sex pheromones are used to capture males before mating occurs. Efficient traps capture a high percentage of the targeted insects that are drawn to the area by the attractant.

The most commonly used chemical attractants are traps. Not all the chemicals used here are pheromones. Chemical attractants are usually impregnated or encased in a rubber or plastic sheath. Most traps use an adhesive-coated surface or funnel-shaped entrance to capture the targeted insects. Traps for some pests are coated with an adhesive which also contains the chemical attractants. Attractant-baited traps are used instead of other sampling methods for two reasons:

(a) Using Attractants to Disrupt Insect Mating

In field application of mating disruption techniques, the attractant is applied to the field or forest in hollow plastic fibre, capsule like pellets and attractant-impregnated plastic strings of ties. Mating disruption programme is not widely used, trials have been used successfully against the oriental fruit moth, pink bollworm in cotton, grape berry worm, tomato pinworm and several pests of forest conifers. The trial use of pheromones to disrupt mating for codling moth control in apples has produced mixed results. Mating disruption programmes are most successful where large areas are treated. When pest densities are low, artificial attractants are more likely to out-compete a high percentage of female insects in attracting males.

Attractants in Poison

Combining insects with insecticides is a practice that has been used in pest management for years. Poisonous baits were used in grasshopper control. Grasshoppers attracted to treated bran to feed were killed by insecticides that could not be applied safely. Since pests are lured to perilous compounds that combine with attractants, poisonous baits can be used effectively at a low rate. Research is being carried out for investigating the use of feeding attractants and feeding arrestants derived from wide squash in combination, when an insecticide was used to control adult corn root worm beetles. Visual lures can be used to attract insects in pest management programme. This is divided into three categories:

- ❖ Light that attract insects from dark or dimly lit surroundings
- ❖ Coloured objects that are attractive because of specific reflection
- ❖ Shapes or silhouettes that stand out against a contrasting background

Light Attractants

A large number of insects are attracted to light. Most traps or other devices that rely on light to attract insects use fluorescent bulbs that emit ultraviolet wavelengths. Most insects that are not pests, such as moths, beetles, flies and other insects, are attracted by light. They may be drawn to the light throughout the night. Many cutworms and armyworms, diamondback moth, sod web worm moths, peach twig borer and several leaf rollers, moths, potato leafhopper, bark beetles, carpet beetle, European corn borer, and codling moths, are all attracted to light. Light and light traps have been used with various degrees of success in monitoring pest population and in mass trapping.

One widely used, but very ineffective, application of light for insect control is the placement of electrocutors or “buz zappers” on lawns or patios. This is effective for two reasons:

- ❖ Many insects attracted to the area because the light is emitted by the trap
- ❖ The lit electrocutors attract and kill a wide range of insects

(b) Coloured Object Attractants

A particular colour attracts some day-flying insects. Yellow or red objects is often used to trap insects. Coloured objects can be used in traps for monitoring or mass trapping. Yellow plastic tubs filled with water are used to monitor the flights of aphids in crops where these insects are important vectors of plant viruses. Aphids are attracted to yellow tub land on the water and are unable to escape. Yellow, sticky-coated cards or plastic cups are widely used in mass trapping programmes to help control whiteflies in greenhouses.

When pest densities are low, artificial attractants are more likely to out-compete a high percentage of female insects in attracting males.

Research indicated that red sphere traps and chemical attractants can be used to trap apple maggot flies and limit damage to fruits. Traps used to capture stable flies around livestock and outdoor recreation facilities are constructed from alsynite, a translucent building material similar to fibre glass. It is attractive to stable flies apparently because of its specific reflectance. Alsynite panels coated with adhesive are used to determine stable fly abundance and their effectiveness in mass trapping is under investigation. They can provide some amount of control of flies in isolated areas. If alsynite traps are to be effective, producers will need to use many traps like:

5.1.14 Allelochemicals

Allelochemicals are semiochemicals that affect one or more species. Volatile compounds similar to those given off by food sources are important in pest management. Feeding attractants are examples of kairomones. Allelochemicals produced by one species are an advantage to other species. For example, carbon dioxide released by humans to other animals is used by female mosquitoes as kairomones. *Allomones are allelochemicals* that favour producers. The secretions that deter predators are *allelomones*.

5.2 CONTROL OF PESTS IN COTTON FIELDS USING ALFALFA PLANTS

In alfalfa farming, trap cropping is a good approach because the alfalfa receives negligible injury. In trap cropping, plants are grown in between crops so as to attract insects, and protect targeted crops from being attacked by pests. Protection may be achieved by preventing them in certain parts of

the field where they can be controlled. Alfalfa can be grown between rows of cotton fields at about 128 rows of cotton and 20 feet strips of alfalfa.

Alfalfa Systems

Inter-planting alfalfa in cotton is reportedly very effective in keeping lygus bugs out of cotton plants. The combination of alfalfa and cotton effectively improves production because pests can be easily controlled. Alfalfa traps pests in the field, thereby preventing them from attacking or feeding on the cotton.

Strip Harvesting

Cotton and alfalfa may be grown or produced adjacent to each other. The alfalfa field, which is a source of western lygus bugs, will increase the movement of the bugs after alfalfa is harvested for hay. To reduce the movement of the bugs, alfalfa can be harvested in alternate strips. When a strip on the other side is half grown, instead of the bug moving to the cotton, it will move to the other side where the alfalfa has not been harvested.

5.3 INDUCED PLANT DISEASE RESISTANCE

The major problem faced in plant production is the difficulty of controlling diseases to maintain high quality yield. For instance, many fungal pathogens have developed resistance to the active ingredients of a wide range of fungicides and there is a public perception that 'pesticides' are undesirable. Scientists have developed a number of approaches (chemical, physical, cultural, and biotechnological) to reduce the incidence of disease in agricultural crops. One of the approaches identified is to control plant diseases through the induction and enhancement of the plant's own defence mechanisms, which would not involve the application of toxic compounds.

The natural protection of plants against pathogens or chewing insects is based on a variety of constitutive barriers already present in the plant before the actual attack. In addition, plants can activate protective mechanisms upon contact with invaders; this is called induced or acquired resistance (Lyon and Newton, 2005). Induced resistance is resistance that is dependent on factors present only after the host is challenged by the pathogen. Recent studies have suggested that inducible defences in plants may have selective advantages over constitutive defences (Agrawal, 1998). Inducible defences are often localized at the site of attack and plant defence mechanisms are activated systemically throughout the plant following a localized infection or attack (Zehnder et al., 1998).

5.3.1 Forms of Induced Resistance

Induced resistance exists in two forms: localized and systemic. As the term implies, localized resistance can be detected only in the area adjacent to the site of penetration by the pathogen. This type of resistance is often accompanied by the rapid collapse and desiccation of the host tissue, a reaction termed hypersensitive response (HR). When resistance spreads systemically throughout the plant and is untreated, it is called systemic acquired/induced resistance (Agrios, 2005). Systemic acquired resistance (SAR) is a mechanism of induced defence that confers long-lasting protection against a broad spectrum of microorganisms like viruses, bacteria, fungi, and oomycetes. SAR refers to a distinct signal transduction pathway that plays an important role in the ability of plants to defend themselves against pathogens (Sharma, 2005).

5.3.2 Mechanisms of Induced Resistance

Induced resistance follows different biochemical interactions that include a 'cascade' of induced responses. This cascade of resistance is induced when a plant recognizes that a potential pathogen is present and compounds that are capable of triggering such responses are termed as elicitors (Lyon and Newton, 2005). It is regulated by a network of interconnected signalling pathways in which the primary components are the plant signalling molecules like salicylic acid, jasmonic acid, and ethylene. The mechanism occurs in the following sequence:

5.3.2.1 Pathogen Recognition

The first step includes the recognition of pathogen by the host plant. The plant receives signal molecules (elicitor), which indicate the presence of pathogens as soon as the pathogen comes in contact with the plant (Sharma, 2005). Various pathogens like bacteria and fungi release a variety of substances which act as non-specific elicitors of pathogen recognition by the host. They are toxins, glycoproteins, carbohydrates, fatty acids, peptides and enzymes like proteases and pectic enzymes. When receptors in the host plant recognize the pathogen elicitor, a series of alarm signals are sent out to the host cell proteins and many biochemical reactions and structural changes take place with an effort to fend off the pathogens and their enzymes and toxic substances.

5.3.2.2 Rapid Active Defences

A characteristic of defence response is the immobilization of wall proteins possibly through the formation of covalent crosslinks and subsequent

barrier formation against pathogens. Elicitor molecules from bacteria and fungi trigger a plant defence response known as oxidative burst, that involves the production of reactive oxygen species (ROS), superoxide and hydrogen peroxide. A change in the membrane permeability takes place which increases the ion movement like K^+ , H^+ , and Ca^{2+} through the cell membrane, accumulation of H_2O_2 ; disruption of membranes and loss of cellular compartmentalization, activation of phenol oxidases and oxidation of phenolics (Agrios, 2005). Rapid generation of superoxide and accumulation of H_2O_2 causes the cell collapse and death.

5.3.2.3 Hypersensitive Responses (HR)

HR is localized induced cell defence in the host plant at the site of infection by a pathogen. HR is the result of quick mobilization of a cascade of defence responses by the affected and surrounding cells, which subsequently release toxic compounds that destroy both the invaded and surrounding cells (Agrios, 2005). Recognition of the elicitors by the host plant activates a cascade of biochemical reactions in the attacked and surrounded plant cells leading to new or altered cell functions, or new activated defence related compounds that provide resistance to the host plant by the pathogen. HR is characterized by a rapid loss of membrane integrated in the infected host cells and the accumulation of brown phenolic compounds.

HR is often associated with the initiation of other responses such as lignification and the synthesis of antimicrobial compounds. The success of hypersensitive death as a resistance mechanism depends on the nutritional requirements of a specific pathogen and the timing, magnitude and location of the host. It is effective against obligate parasites that require living host cells for nutrition because some host responses do not result in the HR (Schmidt and Smith-Becker, 1999).

It is imperative to recognize that HR occurs only in a specific host pathogen in which the host and the pathogen may be incompatible. This may happen as a result of the presence of resistance gene(R) in the plant which recognizes the elicitor from pathogen (Agrios, 2005). Pathogens produce the elicitor that triggers the development of resistance in the host.

5.3.2.4 Production of Antimicrobial Substances

Pathogenesis related proteins (PR) are structurally diverse groups of proteins which are toxic to invading fungal pathogens. They are present in trace amounts in plants but are produced in greater quantities following the attack or stress or treatment with elicitors. The significance of PR proteins lies in the fact that they show strong antifungal and other antimicrobial activities (Sharma, 2005). Some of them inhibit the spore release

germination, while others are associated with strengthening of the cell wall and outgrowth of the papillae. There are different kinds of PR proteins in various plant parts such as roots, leaves and seeds. They can be found intercellularly, intracellularly and in the cell as well. PR proteins like chitinase and glucanase accumulate in the vacuoles. They can dissolve the fungal cell; and the resultant fragments then elicit hypersensitive cell death.

- **Phytoalexins**

Phytoalexins are toxic antimicrobial substances produced in appreciable quantities in plants only after stimulation by phytopathogenic microorganism or by chemical and mechanical injury that inhibits the growth of fungi, bacteria, nematodes and other organisms (Sharma, 2005). It accumulates both resistance and susceptible necrotic tissue. Phytoalexins are produced in cells surrounding the infected site and delivered to the infected cell packaged in lipid vesicles, creating a toxic microenvironment in the infected cell, therefore, preventing establishment of disease. The resistance mainly occurs when one or more phytoalexins reach a concentration sufficient to restrict pathogen development in the plants.

5.3.2.5 Different Pathways

- **Salicylic Acid (SA) Pathway**

SA triggers SAR and moves as a long-distance component of a signal transduction pathway. It participates in SAR and in HR. SA induces the pathogenesis related proteins PR-1, PR-2, PR-5, beta-1,3-glucanase, and glutathione S-transferase and reacts with H_2O_2 scavenging enzyme catalase and ascorbate peroxidase (Agrios, 2005). SA elevates H_2O_2 levels, binds and inhibits the catalase, which degrades H_2O_2 that later induces PR-1 (pathogenesis related protein-1). SA also inhibits ascorbate peroxidase, which scavenges H_2O_2 , but does not inhibit peroxidase involved in lignification and cell wall cross-linking (Matthews, 1999). PR-1 and PR-5 have activity against oomycetes; chitinase have antifungal activity. Matthews (1999) explained in his publication that experiments conducted clearly pointed out that SA is antagonistic to jasmonic acid.

- **Jasmonic Acid (JA) Pathway**

Induced resistances against herbivores are mediated by jasmonic acid as a central signalling molecule (Thaler, 1999). In many plants wounding increases the endogenous levels of JA and also the exogenous application of JA stimulates the expression of defence compounds (Staswick and Lehman, 1999). JA induces the phytoalexins-related enzymes, osmotin, thionin (antifungal), and defensin. Ethylene also plays a role in defence against

pests and pathogens. JA and ethylene together induce PR-3, PR-4, chitinases which act as a physiological signal for defence. It was identified by numerous scientists that nitrous acid plays the same role as ethylene in inducing resistances.

5.3.2.6 Systemic Induced/Acquired Resistance

SAR is long lasting and often confers broad-based resistance to different pathogens. SAR is the activation of defences in uninfected parts of the plant. As a result, the entire plant is more resistant to a secondary infection. Systemic induced resistance in plants is a secondary resistance response after hypersensitive resistance to avirulent pathogens. The signal for SAR may be generated within four to six hours and expression of SAR occurs within 24 hours from inoculation as systemic transportation is carried out by phloem.

SAR requires the signal molecule salicylic acid (SA) and is associated with accumulation of pathogenesis-related proteins, which perhaps contribute to resistance (Durrant and Dong, 2004). This leads to the activation of numerous effectors which are responsible for PR proteins. Concerted expression of these genes results in broad resistance to diverse pathogens. SAR is the over expression of the NIM1/NPR1 gene (Agrios 2005).

5.4 CHARACTERISTICS OF INDUCED RESISTANCE

5.4.1 Multiple Mechanisms

Different mechanisms contribute to induced resistance. Sometimes, induced resistance against many pathogens is initiated by a hypersensitive response and oxidative burst in which plant cells around the site of infection die and may effectively trap and destroy the pathogen (Karaban and Kuc, 1999). In some cases, SAR occurs without hypersensitive responses. Most instances of induced resistance against herbivores lack hypersensitive responses and oxidative bursts (Karaban and Kuc, 1999). Usually, induced resistance against pathogens are localized (Schmidt and Becker, 1999). Some plant responses are apparently very quick, i.e., within an hour after induction. Some are seen in the season following induction. According to Sequeira (1983), they are time-dependent, i.e., resistance is established only after certain metabolic changes occur in the host during a specific interval following the inducing inoculation; they are temperature-dependent, systemic resistance being far more sensitive to this factor than localized resistance; they are affected by light to different degrees, but light is essential only in certain cases of systemic resistance; in both cases, resistance is

persistent once induced. At this stage, the plant response is turned on. From the discussions and factors treated, induced resistance against pathogens and herbivores involves multiple mechanisms.

5.4.2 Lack of Specificity

The second important feature of induced resistance is that it lacks specificity. Many different factors like chemicals, biological and other genetic manipulation can be the cause for it. For example, in some cases herbivores and pathogens elicit distinct responses while in other cases they elicit the same responses. Resistance in cucurbits and tobacco can be induced by infection with viruses, bacteria, fungi, or treatment with a variety of structurally different organic or inorganic compounds (Karaban and Kuc, 1999). The great structural diversity in agents used to elicit SAR makes it clear that activity depends on what elicitors do rather than what they are. Once they are induced, plants can respond to a wide variety of organisms. This may be because of the fact that it shows multiple mechanisms which affect a broad spectrum of pests. In general, SAR is most effective against fungi, less effective against bacteria, and least effective against systemic viruses.

5.4.3 Multiple Pathways

Induced resistance follows multiple pathways. SA pathway is mostly effective against pathogens. It is a simple hydrobenzoic acid which plays an important role in the SAR that develops after an initial pathogen attack. The onset of SAR is associated with increased levels of SA (Pieterse et al., 2001). After SA causes numerous changes including production of a lignin-like barrier, pathogenesis related proteins such as chitinase degrade the structural called chitin of fungi, hydrogen peroxide and peroxidase. The chemicals then produce antibiotics against pathogens and sometimes resist infection by inhibiting penetration (Schmidt et al., 1996).

Some non-pathogenic rhizobacteria follow the distinct signal pathways. They neither produce SA nor show the hypersensitive response, but promote growth and induce resistance against pathogenic viruses, bacteria and fungi. This type of induces resistance is called as rhizobacteria-mediated induced systemic resistance (ISR). It involves the jasmonic acid (JA) and ethylene (ET) pathway. JA pathway is involved mostly against herbivores. Ethylene is another signalling pathway which is involved in induced responses to pathogens and herbivores.

Recognition of the pathways can help to explain the pattern of specificity and cross-resistance mechanisms among different herbivores and pathogen pest that are important tools for pests' management.

5.4.4 Interaction between Pathways

SA, JA, and ET dependent defence pathways can affect each other's signalling mechanisms. The interaction may be synergistic, enhancing the efficiency of the responses, or antagonistic, thereby reducing efficiency when several pathways are simultaneously involved (Karaban and Kuc, 1999). SA dependent defence and JA/ET dependent defences are mutually exclusive due to negative cross talk (Pieterse et al., 2001). The combination of ET and JA induce defence reactions more efficiently than either of these elicitors alone. Inhibition of the JA pathway by SA is the best example for the antagonistic interactions. Treatment with SA prevents wounded plants from the synthesis of JA, because the defence mechanism against herbivores does not work. Sometimes when the responses mediated by jasmonates and salicylates are antagonistic to one another, then insects that stimulate the salicylate pathway and pathogens that stimulate the jasmonates pathway, are indirectly depressing the plant responses and thereby increasing their own fitness (Sharma, 2005). Further, JA also interferes with the resistance mediated by salicylic acid and the plants ability to protect itself against some pathogens. Plants treated with JA produce less pathogenesis related proteins in response to pathogen infection and where induced resistance is less by bacterial infection (Karaban and Kuc, 1999). From this understanding, it may be deduced that there is high interaction between the pathways. That is why it is necessary to know when induced resistance on crops against certain diseases and pests has been administered. This treatment could be done through genetic engineering or by treatment with certain chemicals that mimic the action of specific defence signalling molecules.

5.4.5 Mechanisms of Induced Resistance

Induced resistance can be manipulated by chemical, genetic engineering/ biotechnology and by biological elicitors that involve certain chemicals, heavy metals, non-pathogens and avirulent forms of pathogens, incompatible races of pathogens, or by virulent pathogens under circumstances where infection is stalled due to environmental conditions. In contrast to genetic resistance, induced resistance protects plants from a broad spectrum of pathogens and works systemically in many instances. Among three control measures, biological control of plant pathogens is currently accepted as a key practice in sustainable agriculture because it is based on the management of natural resources and approaches, which are eco-friendly.

5.4.6 Chemical Elicitors

A novel synthetic chemical Benzothiadiazole (BTH) was shown to induce acquired resistance in wheat. BTH protected wheat systemically against powdery mildew infection by affecting multiple steps in the life cycle of the pathogen (Gorlach et al., 1996). BTH is a new product, promoted as a safe, reliable, and non phytotoxic plant protection agent which is used in tobacco, wheat and other important agricultural plants. BTH-treated plants show resistance to infection by turnip crinkle virus, *Pseudomonas* from the SAR-associated genes, PR-1, PR-2 and PR-5 (Lawton et al. 1996). The foliar application of JA has increased levels of polyphenol oxidase, an oxidative enzyme which involves in the induced plant resistance to insect herbivores in tomatoes (Thaler, 1999).

5.4.7 GM Approaches to Plant Disease Resistance

After the discovery of molecules and genes involved in disease resistance in plants, attempts were made to engineer durable disease resistance in economically important crop plants. Scientists from all over the world are investigating the biochemical nature of, and the signals involved in, a plant's reaction to pathogen invasion and disease development. Plant resistance genes and the genes involved in resistance reactions are being identified and engineered into crop plants to protect them against plant diseases. For example, cloned *NPR1* gene of *Arabidopsis thaliana* is a key regulator of acquired resistance responses. Upon induction, *NPR1* expression is elevated and the *NPR1* protein is activated, inducing expression of pathogenesis-related genes (Pieterse et al., 2001).

5.4.8 Biological Elicitor

Development of biological control for plant diseases is accepted as a durable and environmentally friendly alternative for agrochemicals. Plants have the ability to acquire and enhance the level of resistance to pathogen attack after being exposed to specific biotic stimuli such as leaf-chewing herbivores, leaf miners, aphids and even non-pathogenic root-colonizing bacteria to induce resistance to herbivores and pathogens. Non-pathogenic rhizobacteria can induce a systemic resistance in plants that is similar to SAR.

Rhizobacteria-mediated induced systemic resistance (ISR) has demonstrated against fungi, bacteria, and viruses in *Arabidopsis*, bean, carnation, cucumber, radish, tobacco, and tomato under conditions in which the inducing bacteria and the challenging pathogen remained spatially separated. Bacterial strains differ in their ability to induce resistance in different plant species, and plants show variation in the expression of ISR

upon induction by specific bacterial strains. Some of the rhizobacteria induce resistance through the SA-dependent SAR pathway, while others require jasmonic acid and ethylene by the plant for ISR to develop. Although SAR and ISR utilize distinct signal transduction pathways, they require a common intermediate identified by the *NPR1* gene in *Arabidopsis*.

SAR is used to describe induced resistance dependent on SA signalling and associated with the induction of PR genes, while ISR denotes the systemic resistance induced by rhizobacteria that is not dependent on SA signalling and not associated with accumulation of PRs. Usually root-colonizing bacteria enter plant roots and live as endophytes inside the plant. The endophytic behaviour aids in the induction of resistance, because a larger number of plant cells are being contacted by the bacteria than by isolates confined to the rhizosphere (Loon et al., 1998).

Arbuscular mycorrhizal fungi, which form symbiotic associations with a wide range of plant species, are another interesting group of microorganisms that effectively reduce root disease by a number of soil borne pathogens. For example, *Glomus mosseae*, Arbuscular mycorrhizal fungi, is able to confer bio protection against *Phytophthora parasitica* in tomato roots through localized and induced systemic resistance. It is associated with accumulation of phenolics and plant cell defence responses (Cordier et al., 1998).

5.5 DISCUSSION AND CONCLUSION

Systemic Acquired Resistance (SAR) is a defence mechanism that is increasingly being exploited for crop protection. Due to the unique mode of action of the control method—through induction of a cascade of resistance responses, it has the added advantage that pathogens do not develop insensitivity as they do to traditional fungicides. However, successful utilization of SAR requires optimization of defence induction for each crop followed by a determination of pathogens against plants.

Chemical activation of systemic acquired resistance indicates that treatment with suitable compounds may lead to acceptable results in the context of integrated pest management therefore limiting the use of traditional pesticides in favour of non-persistent, non-toxic, low-rate products; such compounds should also be better accepted by farmers and be welcomed by the public (Sharma, 2005).

To reduce the dependence on chemical crop protection for disease control in agriculture, biological agents are receiving increasing attention. Benzothiadiazole, a chemical inducer of SAR, is currently being commercialized as an activator of natural plant defences. Resistance-inducing rhizobacteria offer an attractive alternative in providing a natural, safe,

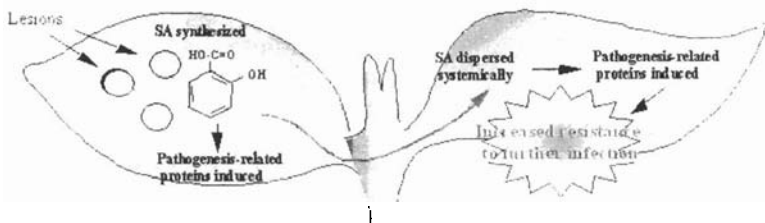
effective, persistent and durable type of protection. Protection based on biological agents is not always reliable and is seldom as effective as chemical treatments. However, different treatments may be combined, and combinations of biocontrol agents that suppress diseases by complementary mechanisms may further reduce disease outbreak (Sharma, 2005).

An approach to new synthetic inducers of systemic acquired resistances requires knowledge of the target on which their action depends. It is, therefore, imperative to understand how the manipulation of plant resistance influences the community of organisms' feeding on plants. Induction of resistance causes vast changes in plants and the changes affect a broad variety of organisms, many of which have the potential to affect plant yield. The connection between the chemical changes induced by the elicitor and the effects that the changes have on plants and their associated organisms in the field is critical to make the elicitor as a pest management tool.

However, some drawbacks that are associated with induced resistance cannot be ignored. When different types of attacks, such as insects and pathogens, occurs simultaneously in the field, potential trade offs may arise from negative interactions between the two pathways mediated by JA and SA, respectively. These conflicts might increase vulnerability to insects when plants are induced to express SAR against pathogens (Gozzo, 2004).

A more general question posed by induced resistance is whether it incurs fitness costs. Several mutants of *Arabidopsis* as well as plants manipulated by engineered bacteria, expressing high levels of SA, have exhibited stunted phenotypes resulting in reduced growth and seed set (Gozzo, 2004). Therefore, it is necessary to consider fitness costs of chemical induction of SAR over plant growth and development. PR proteins often possess allergenic properties, so there could be a possibility of food allergy. Not one of the above-mentioned costs is probably high enough to compromise the benefits of synthetic inducers of SAR, but the uncertainty of some potential side effects may delay its commercialization.

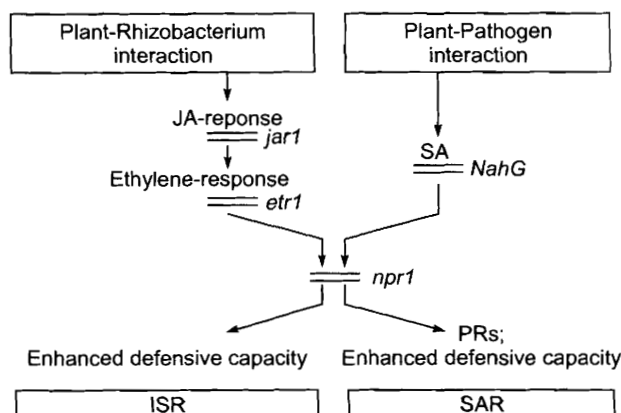
Figure 7 shows the model for SAR based on the dispersal of salicylic acid.



Source: Anonymous (NN 2) 2003

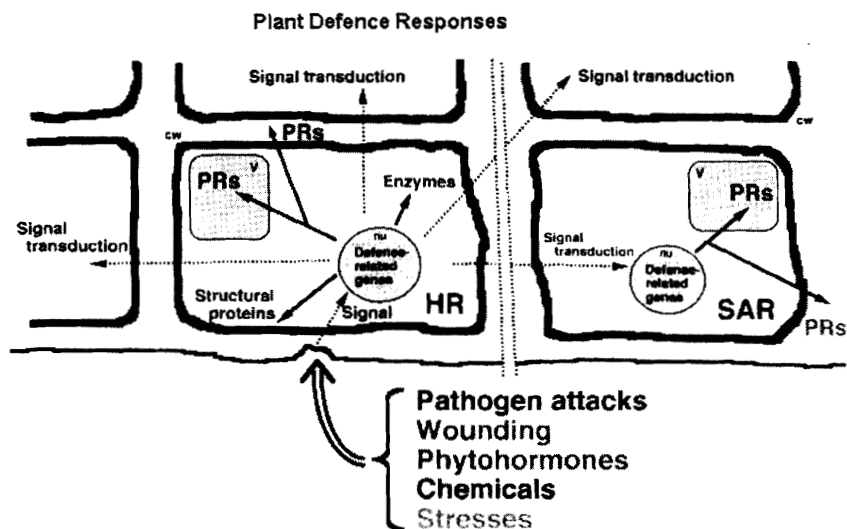
Fig. 7 Systemic induced resistance

Rhizobacteria Mediated ISR



Source: Loon et al. (1998)

Fig. 8 Signal transduction pathway for SAR and ISR in *Arabidopsis thaliana*.



Source: Anonymous (2003)

Fig. 9 Mechanisms of systemic induced resistance showing production and accumulation of enzymes, PR proteins, HR and signal transduction.

Weed Management

6

Chapter

Weed management is a major constraint in organic production. Weeds can be very expensive to control, the process is time consuming and causes severe loss to crop yield when not adequately controlled. Weeds are considered to be notorious and very difficult to control in organic agriculture (Kristiansen, 2003). The survey conducted on organic growers in many countries for more than a decade shows that weeds are prime constraints affecting organic agriculture, especially during the period of conversion.

Reports from organic farmers and certification bodies also confirmed that weed control is the main impediment faced when converting from conventional to organic method. Wynen (1992) explained that a number of difficulties may be encountered during the conversion period to organic agriculture, due to lack of proper understanding of the significant changes that may occur in weed population control. Research also conducted on organic farming by numerous authors reviewed that weeds are a major problem in crop production. The research result explained that weed control caused significant reduction to crops which leads to increase in the cost of production. Wynen, 1997; Köpke, 1999; Willer and Yussefi, 2000 pointed out that there are rankings in weed control. As a result of the constraints caused by weeds to production, it is imperative that the various institutions conduct a more intensive and comprehensive research, which should be geared towards modern strategies required in the control.

When comparing control of weeds in conventional and organic farming, labour costs in organic farming appear to be greater. The extra on-farm labour on organic properties is usually considered to be greater due to higher requirements for weeding (Stonehouse et al., 1996; Clark et al., 1999; Nilsson et al., 2000). The spreading of compost and the use of fresh grass as mulch on soil surface can suppress weed growth and development. This assertion is in line with the conclusion made on weed eradication by Schonbeck and Evanylo, 1998 and Clark, 1999. The high cost of weed control

in organic farming as pointed out by Melander, 1998; Alemán, 2001; Porter et al., 2003 is due to labour cost, farm size, prevailing weed density, crop value and access to premium prices.

6.1 BENEFICIAL ASPECTS OF WEEDS

Despite the number of reports on the negative impacts of weeds in organic and conventional farming, a lot of reports and researches proved that weeds have beneficial effects on both crop production and human health.

The beneficial impacts of weeds are:

- ❖ Providing industrial materials, medicinal plants, and food for stock.
- ❖ Providing diverse habitats for soil microbes.
- ❖ Accessing nutrients in the sub-soil, storing minerals to reduce leaching, providing green manure.
- ❖ Loosening heavy or compacted soil and sub-soil, providing ground cover to reduce erosion and surface crusting.
- ❖ Reducing leaching and surface runoff.
- ❖ Indicating underlying soil conditions, providing habitat and resources for beneficial invertebrates.

Weed Classifications

Weeds are either classified as grasses or broadleaves. There are many plants that resemble weeds and some of them can mistakenly be called grasses even though they are not true grasses. Some of these weeds are rushes, sedges and lilies.

In most cases, weeds are classified according to their lifecycle. They can either be annual, biennial or perennial. Annual weeds usually complete their life cycle within one growing season. This cycle may occur in winter or summer based on the plant species. They grow from seeds on any recently cultivated soil. The seeds can survive for many years in the soil while waiting for a perfect condition for re-germination. In most cases, they thrive well in a lower temperature than most garden plants. This group of weeds includes: *amaranthus retrofolia*, *ambrosia artemisiifolia*, *euphorbia supine*, etc.

Biennial weeds reproduce by means of seed but die within two growing seasons. The first growing season represents a vegetative phase whereby the plant grows and accumulates food reserve. This is followed by flowering and seed production in the second growing season. Biennial weeds usually die after the plant flowers. The common biennial weeds in pastureland include: bull thistle, plumeless thistle, musk thistle, wild parsnip and spotted knapweed, etc.

Perennial weeds persist for more than two growing seasons. They may be woody tissue which may remain above the ground or may be a rootstock that survives in the soil and re-grow new vegetation yearly. However, some perennial weeds may grow for many years before seeds are produced. The weeds can be spread by vegetative means or through seeds. Some examples of perennial weeds include: *epilobium glandulosum*, *oxalis europaea*, *plantago major*, etc.

Due to the chemicals presently being used for the control of weeds in conventional farms, it is advisable that farmers embarking on this pre-emerge herbicide in accordance with the expected date of emergence for each targeted species. From the organic point of view, the use of chemical control has several adverse effects on human health and the environment. It is best to use natural enemies and cultural practices for weed control in order to ensure human safety and environmental protection.

Farmers who rely on chemicals should be aware of the accurate timing of the applications, proper rate of applications and uniformity of applications. They should adhere to the directions as labelled by the producer and should observe all warnings and precautions relating to safety of the application.

6.2 ORGANIC WEED CONTROL

Organic farmers have focused on weed control without recourse to herbicides; they rely mainly on a large suite of strategies and tools to manage weeds. Altieri and Liebman (1988b) suggested in their literature that two main methods can be used to control weeds in organic farming: (a) direct control, where the weeds are physically suppressed or removed, and (b) indirect control, which gives the crop a competitive advantage over the weeds using cultural or management techniques.

A lot of literature review has also shown that crop rotation helps suppress growth of weeds in both organic and conventional farming. It was suggested that the crop rotation system is more effective than concentrating on monoculture. In dealing with species-rich weed communities, indirect methods are likely to be more effective (Altieri and Liebman, 1988b; Barberi, 2002). The National Standards for organic production in Australia listed the following practices for organic weed control:

- ❖ Choice of appropriate species and varieties
- ❖ Biological controls, such as crop rotations, biodynamic measures, solarization, tillage, mulching, mowing and grazing.

The standard set also included cultural control methods like stimulating soil fertility, growing green manure crops, and using careful sowing and cultivation techniques.

A summary of direct (or physical) and indirect (or cultural) weed control practices used in organic herb and vegetable production is given in Table 5.

Table 5 Direct and indirect weed control

<i>Direct/Physical Methods</i>	<i>Indirect/Cultural Methods</i>
Tillage: Mechanical cultivation of soil before and during the cropping phase Hand weeding, hoeing or pulling	Rotation: Varying crops, cover crops, fallows and grazing
Mulching: Organic materials, use of woven plastic weed mat is restricted	Cover crops: Green manure or other crops grown in fallow period to suppress weed growth
Slashing: Slashing or mowing using hand-operated implements	Prevention: Reducing weed seedlings and avoiding weed seed production
Grazing: Using a wide range of grazing animals to suppress weeds	Timing: Strategic timing of planting, tillage, fertilization, irrigation systems and cover crops
Biological methods: Classical, inundative, myco-herbicide methods available	Planting density: Increased usually, but some crops (e.g., cotton) use wider spacing to allow access for tillage implements
Solarization: Requirements to be effective, limitations (e.g., selective control only)	Intercropping: Growing two or more crops in close proximity to improve resource capture

Source: Kristiansen (2003)

Plant Nutrients and Nutrient Utilization

7

Chapter

Continuous cropping without adequate restorative practices may endanger the sustainability of agriculture (FAO, 2003). Nutrient depletion is considered a major form of soil degradation. An in-depth study of the depletion of plant nutrients from soils will help understand the state of soil degradation and may be useful in devising nutrient management strategies. Nutrient-balance exercises may serve as an instrument to provide indicators for the sustainability of agricultural systems.

Most nutrient-balance studies provide rapid findings, based on a short time frame exercise, however this depend on a number of assumptions relating to system dynamics. Although, series of questions have been raised as to whether nutrient budgets provide the information required for understanding the status and dynamics of soil fertility across farming systems and whether such analysis may provide reliable direction and support to policy formulation on soil fertility management (Scoones and Toulmin, 1998).

Plant nutrients can be divided into macro and micro elements. The macronutrients are required by plants in large quantities. The application of major nutrients in the soil in a very low quantity leads to nonavailability of nutrients for plant usage. Macronutrients include nitrogen, phosphorus, calcium, potassium, magnesium, oxygen, sulphur and carbon. The micronutrients are required in small amounts. However, excess quantities may lead to nonavailability of nutrients for plant usage as well. Micronutrients include cobalt, manganese, boron, iron, copper, lead, zinc, molybdenum and chlorine.

7.1 MAJOR ELEMENTS

(a) Nitrogen (N)

Nitrogen is an important building block of proteins, nucleic acids and other cellular constituents that are essential for all forms of life. Nitrogen is an

extremely vital key nutrient element for plants that warrants careful management, and if mismanaged, can lead to severe environmental problems (<http://www.cpit.ac.nz/subjects/horticulture/documents/nitrogen.pdf>).

Of all the major plant nutrients, nitrogen is often the most important determinant of plant growth and crop yield. Plants lacking nitrogen displays stunted growth and yellowish leaves. Plant growth and crop yield usually increase when nitrogen is added, despite the presence of nitrogen in soils. This is because most of the nitrogen in soils is stored within the soil humus in the forms that cannot easily be accessed by plants.

Nitrogen in the soil cannot be obtained from analysis of surface soil samples submitted for routine soil testing. Over the last decade, research has been directed towards optimization of nitrogen fertilizer supply for vegetable crops. The main focus has shifted to increasing nitrogen use efficiency. The improvement of nitrogen utilization efficiency for vegetable crops has created room for a proper approach for the use of nitrogen in both developed and developing countries.

Currently, different approaches and methods are in use to attempt nitrogen use efficiency on single crop, rather than crop rotation. Occasionally, mineral nitrogen may be available in deeper soil layers, which cannot be accessed by some crops, but can be used by other crops with a deeper root system.

A number of cultivation measures can be used to improve the nitrogen use efficiency at crop rotation level. The tools to improve nitrogen use efficiency in crop rotation level are, for example, alteration of cropping sequence, changing the time or the way soil is tilled, and the use of catch crops (Kristensen, 2002).

Organic growers are utilizing leguminous cover crops as green manure in rotation to meet nitrogen needs of cash crops. Leguminous cover crops “fix” significant amounts of nitrogen for use by subsequent crops. Through a symbiotic fixation, Rhizobia bacteria convert atmospheric N_2 into an organic form that the legume uses for growth. Cover crop nitrogen accumulation depends on the duration of the growing season, local climate, and soil conditions (Baldwin, 2001).

Baldwin (2001) indicates that leguminous residues contain P, K, and other nutrients which are recycled in relatively available forms for subsequent crop use. Leguminous cover crops make nitrogen (relative to manure, compost, or other “complete” fertilizers), phosphorus and other trace metal (in particular, Cu and Zn) available in the soil for plant usage.

The removal of legume or other trap crop biomass from the field will provide a means of reducing soil concentration of other nutrients from the soil.

Table 6 Recommended legumes for organic sources

<i>Legume</i>	<i>Aboveground Biomass (lbs/acre)</i>	<i>Aboveground Biomass (lbs/acre)</i>
Soybean	3,000–7,000	50–100
Cowpea	3,000–7,000	60–90
Velvet bean	4,000–7,000	20–70
Sunn hemp	5,000–7,000	80–160
Indigo	3,000–9,000	60–90
Lablab	3,000–5,000	20–45

Source: Creamer and Baldwin (1999)

However, poor growing conditions in the previous years and low rainfall during cool seasons have resulted in significant nitrogen to remain in the soil profile.

Farmers should increase or decrease nitrogen rate if a local situation indicates that a change is desirable. Excess nitrogen application before harvest will cause excessive vegetative growth and delay harvest of crops.

Farmers should be aware that nitrogen should not be applied to leguminous crops because they benefit from atmospheric nitrogen fixed by soil microorganisms that are associated with the root legumes.

Organic nitrogen that contains biosolids and manure are changed into ammonium before being made available for plant uptake. This conversion process is known as mineralization. The conversion occurs naturally in the soil by microorganisms and occurs as plant residues and other organic substances. This process occurs more rapidly during warm seasons compared to cool seasons. Once nitrogen is in an ammonium form, it is converted to nitrate by soil microorganisms again within one to three weeks, though most of the organic nitrogen in the soil takes years to change into plant-available forms. In the meantime, microorganisms in the soil assimilate this conversion to release some of the nitrogen through decomposition into nonavailable organic forms that are eventually incorporated and stored within the soil humus. Excess nitrogen can lead to accumulation of nitrate in the edible foliage of plants such as spinach and forage crops. Ingestion of such high-nitrate foods can pose possible health risks to animals and humans.

The problems posed to the environment occur when excess nitrogen in the soils is carried away with surface runoff and water moving through

soils, and flows to potable water and other ecosystems that can also receive nitrogen from precipitation. Most of this nitrogen is in soluble forms, such as nitrate and ammonium.

Organic producers use a lot of plant by-products as a source of nitrogen for crops. Bagged alfalfa, cottonseed, and soybean meal are available as registered fertilizer products with a guaranteed analysis of soluble N, P_2O_5 , and K_2O just like any commercial inorganic fertilizer product (Baldwin, 2001).

Time of Application

Nitrogen fertilizer should be applied at planting, or as close as practical, to the time when it is required by crops. Split applications of nitrogen are a way to achieve this. The recommended nitrogen to be applied on a small grain field should be a minimum of 20 to 30% and it should be top-dressed. It should be applied to maize plots when they are about 18 to 30 inches high on side dressed. This practice conserves resources, saves money by maximizing fertilizer use efficiency, and protects water resources.

(b) Phosphorus (P)

Phosphorus is regarded as the second most important element required by plants. A large number of phosphorus fertilizers are available in the market. Organic producers may have a difficult time in determining which material to use and how much to apply. By law, phosphorus fertilizer is sold on the basis of available phosphate, which is often determined by measuring the amount of P_2O_5 that dissolves in a weak citric acid solution (Baldwin, 2001).

Organic producers have been using bone meal, a by-product of the livestock as a source of phosphorus, for several years. Bone meal contains approximately 27% total P_2O_5 , most of which is available. There is a great deal of confusion about the P_2O_5 content of bone meal because it is sold as a feed additive (Baldwin, 2001). In the food industry, phosphorus is expressed on the label as elemental P, while in the fertilizer industry it is expressed as P_2O_5 ($P \times 2.29 = P_2O_5$). Baldwin (2001) recommended that growers should be aware of the differences when comparing costs of P sources.

The result of research has shown that phosphorus in fertilizers usually remains in the soil surface. It was reported that most phosphorus in soil is normally not available to plants due to it being tightly bound to soil particles, or precipitated as aluminium, iron, and calcium compounds, which have extremely low solubility in water. Some phosphorus may wash down the soil when soil available phosphorus reaches a very high level in coarse textured soils due to soil group. Phosphorus, however, is not lost by

leaching in most cases, though there may be some downward movement as a result of tillage.

As phosphorus is not depleted by leaching, surface losses may be an issue. The loss of phosphorus from the soil can be attributed to erosion, because it is attached to soil particles. Farmers should be aware that surface waters enriched with phosphorus could stimulate growth of aquatic plants like algae.

Factors Contributing to Phosphorus Availability

Soil acidity, soil moisture and temperature are sometimes associated with phosphorus availability. The effect of soil temperature on the response of grain seeds to phosphorus is perhaps most prominently observed by researchers. In the cold season, purple colouration of corn leaves may be seen due to phosphorus deficiency. The effect may not be influenced by phosphorus nonavailability, but it may be due to slow root growth and a lower rate of absorption by plant roots in the cold soil.

(c) Potassium (K)

Potassium is a nutrient plants needed for internal chemistry. Plants use potassium to produce sugars, starches, proteins and enzymes, which they need for growing and thriving. Potassium also helps plants to regulate water usage and withstand cold weather.

Interestingly enough, plants take greater quantity of potassium out of the soil than any other element, except for nitrogen and calcium. Only 1% of potassium occurring naturally in the soil is in plant form. The usable matter is called exchangeable potassium (not to be confused with the conservationist's exchangeable cardigan). When shopping for plant foods and fertilizers, it should be ensured that potassium is included as it plays an essential role in the life of plants. Plants get access to potassium by penetrating their roots through the soil.

Organic potash (K_2O) as noted by Baldwin (2001) provides phosphorus to plants. Its sources are similar to organic phosphates but it has differing nutrient availability and agronomic values. Two sources of K_2O are potassium sulphate and potassium magnesium sulphate (langbeinite), both of which are commonly used in organic and conventional agriculture. Potassium sulphate and potassium magnesium sulphate are available in natural deposits. However, most potassium sulphate fertilizers are manufactured by reacting sulphuric acid with potassium chloride under very high electric current.

Baldwin (2001) mentioned that certain micas like biotite (black mica) contain huge amounts of K_2O . Due to the physical structure of mica, the available K_2O is in relatively microbial active environments.

(d) Calcium (Ca)

Calcium requirements for most crops are supplied based on lime recommendation. When calcium level becomes low, a small amount of lime (320 to 800 kg per acre) may be used to correct deficiency if soil pH is not very high. The possibility of inducing micronutrient deficiency sometimes may not exist. If soil pH is too high, another source of calcium like gypsum should be used. This increases bacteriological activities such as nitrogen fixation by both symbiotic and non-symbiotic bacteria (Akinsanmi, 1994). Gypsum maintains calcium level in the soil. Crops in most cases are very sensitive to low calcium levels. Such crops include peanuts, tomatoes, nuts, pimentos and fruits. Calcium strengthens plant cell walls and controls the toxicity of ions in plants Al^{3+} , Mn^{3+} , Mg^{3+} and Na^+ (Akinsanmi, 1994).

(e) Magnesium (Mg)

The functions of magnesium in the soil are similar to those of calcium. Magnesium is carried by limestone (Akinsanmi, 1994). The requirements of magnesium are usually supplied most economically by using dolomitic limestone. Soil acidity, low magnesium, and low calcium can be corrected by dolomitic limestone at a recommended rate. When magnesium deficiency occurs, it is often due to low soil pH. When lime is required and soil test for magnesium is medium or less, the use of dolomitic limestone is recommended. When lime is required and soil test for magnesium is medium plus or above, any source of lime may be used. The use of dolomitic limestone every time soil is limed will not result in magnesium toxicity or cause a cation imbalance situation in the soils. The application of magnesium oxide, magnesium sulphate, or sulphate of potash-magnesia depends on soil pH. As soil contains adequate magnesium, a magnesium recommendation based on surface soil sample should not be considered to be used on soil. Crops like beet, broccoli, cabbage, carrot, cauliflower, collard, eggplant, onion, pepper, pole bean, spinach, or greens are very susceptible to magnesium deficiency when the pH levels is low.

Magnesium is essential for chlorophyll molecules. The absence of magnesium in the soil affects photosynthesis activities as clearly explained by Akinsanmi (1994). The absence of magnesium will result in chlorosis and there will be streaks along leaves, which in turn results in stunted growth of crops.

7.2 MICRONUTRIENTS

(a) Sulphur (S)

Sulphur is a constituent of plant protein. It provides hormones such as biotin and thiamine to plants (Akinsanmi, 1994). It can be obtained naturally from most soils containing enough organic matters. Rainfall can contribute to approximately 8 to 11 kgs of sulphur per acre in a year. The sources of sulphur are air pollutants from natural and artificial sources. Sulphur deposition varies from year to year, depending on the distance from a large town or smokestack and weather conditions. The addition of sulphur to the soil in the form of farmyard manure, rainwater and fertilizers will relieve deficiency in the soil (Akinsanmi, 1994).

During periods of low temperature and/or when excessive rainfall occurs, sulphur deficiencies are likely to be observed in plants, especially corn growing in sandy soils. Plants usually recover when roots reach the subsoil zone where sulphur has accumulated.

Excessive sulphur can be obtained from the soil in the absence of fertilizer and pesticide applications. Excess sulphur, however, may lower soil pH to a level that could interfere with good crop production.

(b) Boron (B)

Soil test for boron is included as a part of standard soil test. When extractable boron is 0.1 kg per acre or more, it means there is adequate boron in the soil. Plant analysis is the best method for determining when boron is actually needed. Boron in the soil can occur in both organic and inorganic forms. There may be 20 to 200 lb/acre in the surface layer of soil, but only a small amount is available. Boron is made available by the mineralization of soil organic matter, and as boron-containing minerals slowly dissolve into the soil. Boron is often added to the soil as a contaminant of soil amendments. Investigations reveal that manure, superphosphate, and lime are sources of boron.

There is an established relationship between boron and other nutrient elements. The relationship is established between calcium, potassium, and nitrogen as they can affect boron nutrition availability in the soil. The calcium-boron relationship is the most important. Soils with high calcium will need more boron. Lower rates of boron will be required for soils low in calcium, thereby reducing chances of boron toxicity.

Boron toxicity is definitely possible, and care must be taken not to exceed the recommended rates in order to avoid chlorosis in plants. The amount of boron required depends on the crop and soil conditions.

(c) Zinc (Zn)

Zinc is an essential micronutrient required for the normal growth and development of crop plants (Jones and Jarvis, 1981). It acts as divalent cation in plants metabolic system and is an essential constituent of certain metallo enzymes taking part in metabolism of plants (Romheld and Marschner, 1991). In rice plants, zinc is associated with the production of auxin, nitrogen metabolism and activation of many enzymatic reactions (Tisdale et al., 1993). Zinc deficiency causes complex metabolic changes and adversely affects the growth and yield of plants. Zinc is not easily available to plants.

Results of earlier experiments (Ghani et al., 1990; Maqsood et al., 1999) show that rice yield increased with zinc application on alkaline and calcareous soils. Zinc, therefore, is considered an essential element for rice crop that requires to be supplemented with the use of Zn fertilizer. The present study carried out was to investigate the effect of zinc fertilizer on the extractable zinc content of soil and its chemical composition in rice variety.

(d) Iron (Fe)

Iron exists primarily in an insoluble form and is not freely available to plants. Thus, complex strategies involving chelators, production of reductive agents, reductase activities, proton-mediated processes, specialized storage proteins, and others, act in concert to mobilize iron from the environment into plants and within plants. Due to the fundamental role played by iron in plant productivity and ultimately in human nutrition, there have been several debates regarding its utilization in an intense form as clearly indicated by Magdalena and Lamattina, (2005). A lot of debate on iron usage confirms that it is an essential element for all forms of life. Its limitation will have a profound impact on the productivity of photosynthetic organisms (Martin et al., 1994).

Iron deficiency in plants in most cases is not a result of its insufficiency in soil, but due to other conditions such as high soil pH, low soil oxygen levels caused by waterlogging or prolonged periods of excessive soil moisture, high temperature, and abundant phosphorus, copper, manganese, and zinc. Iron deficiencies are pecans (when over fertilized with zinc), centipede grass, blueberries, and certain ornamentals like azaleas and camellias. Application of iron in the soil in a foliar form to correct iron deficiency is the most effective form. Iron strengthens roots and stems, and promote metabolism in plants.

(e) Molybdenum (Mo)

Molybdenum is absorbed by plants in the form of MoO_4^{2-} . Plants grow without molybdenum if nitrogen in the form of ammonium ion is abundant.

Molybdenum is very useful when available nitrogen is in the form of nitrate. The presence of molybdenum helps in plant nitrogen utilization and fixation.

Molybdenum is an essential element in plant life for the uptake of nitrogen from both nitrogen gas and nitrate, yet it is a relatively rare heavy trace element. It also functions in a few extremely important oxygen-atom transfer reactions at low redox potential according to Williams and Frausto da Silva, 2002. Literature reviews that molybdenum is greatly needed by rhizobia bacteria during N_2 fixation from root nodules of legumes. The usage and incorporation of molybdenum to crops and animals is dependent on its availability.

Nanosized metallic molybdenum could be synthesized from MoO_3 and KBH_4 by solid-state reaction at moderate temperature as indicated by Li et al., 2004. The crystallinity, morphology, and surface properties of as-synthesized metallic molybdenum were investigated by powder x-ray diffraction (XRD), transmission electron microscopy (TEM), and x-ray photoelectron spectral (XPS). The results of its catalytic activity test show that the as-synthesized nanosized metallic molybdenum is superior to the noble metal catalyst 0.3% Pd/ Al_2O_3 for the selective hydrogenation of alkadienes at higher temperature and pressure.

Nanosized materials have received much research and industrial attention because of their unique physico-chemical properties compared with the properties of corresponding materials with large grains (Li et al., 2004). Molybdenum is found to be extremely useful to plants. Its deficiency in plants will lead to chlorosis and reduced production of leaves. It may also lead to low nitrogen availability to plants.

7.3 CAUSES OF NUTRIENT LOSS AND SOLUTIONS

Research report x-ray explained that soils of the entire world have become severely demineralized by erosion over thousands of years. Plants require a continuous intake of minerals, just as humans do, and for very similar reasons—calcium for building structural support, iron for carrying oxygen, etc. Plants growing on mineral-depleted soil do not get enough nourishment and so the produce become smaller, less abundant with reduced taste, and more vulnerable to insects, worms and fungi that prey upon them.

The population-driven change from the still predominantly subsistence-oriented agropastoral cropping systems of Sudano-Sahelian in West Africa, which is characterized by heavy nutrient mining (Stoorvogel and Smaling, 1994) and low production levels, to more sustainable market-oriented systems of higher productivity that require the analysis of cause-effect

relationships operating in the present system as well as the development of improved scientifically sound knowledge, cost effective and highly efficient methods of nutrient recycling and nutrient inputs. There has been a strong decrease in the ratio of grazing land to cropping land in most of African countries. This continuous decrease has called for an intensive research to optimize farmers' traditional manure application strategies by decreasing unproductive losses (Murwira et al., 1995; Brouwer and Powell, 1998). In Sahel, typical manure application rates of over $10 \text{ t/ha}^{-1} \text{ yr}^{-1}$ have been reported for the confined areas (corrals) of 10 to 20 m diameter close to famers' homesteads in the cropland; whereas application rates in uncorraled manured fields average 1.5 t/ha^{-1} (Powell and Williams, 1993). Given the low buffering capacities of the predominantly acid sandy soils, this uneven distribution of manure contributes to the marked pattern of variability in crop growth over short distances (microvariability) often described as characteristic for Sahel (Brouwer et al., 1993; Buerkert et al., 1996).

Remineralization has been shown to cause: (a) phenomenal growth in microorganisms in the soil, (b) increased nutrient intake in plants, (c) reduced effects of soil acidity, (d) prevention of soil erosion, (e) increased storage capacity of soil, and (f) contribution to the building of precious humus complexes. Remineralization of soil helps build up plant resistance to insects, diseases, frost, and drought. It can restore productivity after repeated cropping of acid sandy soils.

Hiernaux, 1983; Krul et al., 1982 reviewed that fallow periods of between 10 and 30 years allow the enrichment of topsoil with mineral nutrients and organic carbon by diazotrophic N_2 -fixation from the herbaceous layer or shrubs of the order of $5 \text{ to } 10 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ and $400 \text{ to } 500 \text{ kg ha}^{-1} \text{ yr}^{-1}$ of decay products from leaf, twig and fruit products of woody plants.

The addition of composts and manures to soils has often resulted in increased plant yields that are not obviously related to the nutrients in the added organic material. A study was conducted to determine whether compost additions to the soil result in increased mineralization of soil organic matter (SOM). The organic matter of a Sassafras sandy loam soil (fine-loamy, siliceous, mesic Typic Hapludult) was labelled with C by incubating uniformly labelled wheat (*Triticum aestivum* L.) straw with the soil through a minimum of 60 wetting-drying cycles during two years. A municipal solid waste-biosolids compost (MSWC) or a biosolids compost (BC) was added to the labelled soil or to acid-washed sand and incubated for 1440 hours. Decomposition of municipal solid waste compost was low with 95% of the compost-C remaining in sand or soil after 1440 hours (Sikora and

Yakovchenko, 1996). Ninety-two percent of biosolid compost C remained in the sand and 86% remained in the soil after 1440 hours.

From the data analysis, the municipal solid waste-biosolids compost reduced slightly during SOM decomposition at 545 and 715 hours. The soil, however, stimulated biosolid compost (BC) decomposition. Nitrogen mineralization of the BC + soil mixture was greater than soil alone, and the nitrogen apparently came from the compost. The benefits from addition of BC to Sassafras soil was not attributed to increased mineralization of SOM (Sikora and Yakovchenko, 1996).

It was, therefore, concluded that the incorporation of organic materials, such as municipal waste (MSW) compost, into soil promotes microbiological activity (García et al., 2000). Microbial activity and soil fertility are generally closely related because it is through the biomass that the mineralization of the important organic elements such as carbon, nitrogen, phosphorus and sulphur occur (Frankenberger and Dick, 1983). Studies of microbial biomass C and enzyme activities provide information on the biochemical processes occurring in the soil and it has been proven that there is a growing evidence that soil biological parameters may have a potential as early and sensitive indicators of soil ecological stress and restoration (Dick and Tabatabai, 1992).

In many arable agricultural soils, the soil microbial biomass is related to the soil organic matter content (Houot and Chaussod, 1995) and biomass C generally represents 2–3% of soil organic C (Anderson and Domsch, 1989). García et al. (1994) explained that soils in semiarid areas have a very low microbial activity, low levels of microbial biomass and a low organic matter content. It was also mentioned that due to the increased oxidation after cultivation, tillage operations cause physical disruption on soil surface, and erosion of top soil rich in organic matter (Smith et al., 1993). Thus, microbial biomass, being the living part of soil organic matter, can be a good index for comparing natural (Ross et al., 1982) and degraded (Sparling et al., 1981) ecosystems.

The use of municipal solid waste and sewage sludge compost is the result of based on environmentally and economically sound alternatives. Compost of sewage sludge and organic fraction of municipal solid can enhance agricultural quality and its suitability for use. The presence of heavy metal in raw materials is one of the most serious problems affecting agricultural production. Natural zeolite, however, has the ability by ion exchange to uptake these metals (Antinis et al., 2002). The use of 25% clinoptilolite during composting, 100% of Cd, 27% of Cu, 13% of Cr, 20% of Fe, 37% of Ni, 50% of Pb and 55% of Zn can be absorbed by zeolite. The use of zeolite in

agriculture can retain heavy metals and do not let them pass from the roots to final product and ground water.

The use of natural zeolite, clinoptilolite has the ability to uptake the heavy metals not suitable for agricultural production. Zeolite can be used in catalysis, in air enrichment, as fillers in paper, rubber industry, soil beneficiation, as animal feed supplement and in water and wastewater treatment for ammonia and the removal of heavy metals. It is known worldwide because of its cation exchange or molecular sieving properties. An investigation conducted on zeolite fertilizers application shows that it can increase crop growth and yield in a significant manner. Applying fertilizers in amounts of 150 t/ha and 300 t/ha can result in the increase of biological productivity of crops. Zeolite fertilizers containing 10% of zeolite can be very effective in agronomic practices.

Mechanization of Agriculture

8

Chapter

Modernization of agriculture is a worldwide trend. Modernization and technological inputs are highly interrelated. Among technological innovations, mechanization is perhaps the most critical one. Unfortunately, the history of agricultural policy in many developing countries, including India, is replete with controversies when it comes to mechanization. Mechanization was dubbed as anti-labour, anti-employment, anti-poor, hence needs to be discouraged at any cost according to some “authors”. Over the years, the scare among policy makers about mechanization has receded in its intensity but the phobia has not disappeared. Many economists have also contributed to the predicament of policy makers in regard to implementing appropriate methods needed to mechanized farms. Part of it was ideologically visibly anti-big farmer oriented. In this perspective, mechanization was identified with large farms and big farmers (Narasimha Rao, 2003).

The present study about the impact of mechanization is able to pinpoint with a great deal of accuracy, the desirable consequences and welcome features of mechanization. It is able to explore the effects of mechanization on farm income, employment, productivity and economic efficiency in crop production. The arguments that have been made in the present study regarding the social costs and benefits of the existing pattern of mechanization lead to the conclusion that net social benefits are positive. Analysis of data from the present study also indicates that the existing pattern of mechanization does not add to unemployment, where the thrust is to expand agricultural output, because machines are used in response to worthwhile techno-economic considerations and high cost of maintaining draught powered animals. As machines help to save resources so animals help to solve the problem of labour shortage. The use of farm animals in performing farm activities have increased farmers’ income and may be socially be beneficial whenever there is high cost of agricultural

commodities. The increase in the scale of operation, the rise in the crop intensity and yield made possible by mechanization. Mechanization can lead to a net increase in farm employment. Being in an age of technology, this beneficial fallout from mechanization cannot be ignored (Narasimha Rao, 2003).

Many advancements in farming techniques and tools have manifested since agriculture began thousands of years ago. The greatest strides have occurred in the last 300 years. A substantial contribution to Oklahoma agriculture has been the escalation from manual and stock-animal labour to steam, and then gas-powered implements. Although steel ploughs, mowers, mechanical reapers, seed drills, and threshers contributed to the development of agriculture, tractors have enabled farmers to sow and harvest large areas with less manpower.

Many large farmers used outdated tools and horse power for the daily farm work and only depended on steam-powered and later gas-powered harvesting crews to produce crops. Entrepreneurs buy combines harvesters and other equipment, and hire themselves out to farmers following the harvest.

Another consequence of mechanization of agriculture is the preponderance of truck farming. The increasing popularity of trucks, coupled with the development of better roads, has led farmers to sell their own produce in farmer's markets and along highways. Today, the use of aeroplanes facilitates the spread of pesticides on a large field within a very short span of time. However, the use of herbicides and pesticides is not favoured by organic farmers. They believe the use of these chemicals are harmful to man.

8.1 AGRICULTURAL CHANGES

Changes in the nature and pattern of farming have had a big impact on the types of machines used in current agricultural production. The sizes of farms have increased marginally pursuant to the use of more complicated farm equipment, though may have adverse effect on the soil. The extra scale has resulted in the need to use bigger tractors and machines in order to achieve efficiencies of food production and to meet the current world growth. Moroney (2003) examines the changes that have occurred in the use of machineries on Irish agriculture and the trends for future. He concluded that the number of tractors on Irish farms has remained relatively unchanged for more than 10 years now. He further pointed out that taking tractor numbers as an indication of change will give rise to the view that the industry is stable in a mechanization sense.

Looking at African agriculture, mechanization has improved production efficiency greatly. On the other hand, mechanization as described in African

agriculture, does not only involve the use of machineries, but other implements as well. However, the use of machines has facilitated production but has caused significant reduction in human employment opportunities. In this case, is there a need to increase farm machines?

Increase in power has come about by the removal of older tractors from developed countries to third world export markets. This act, however, is not advantageous to the developing countries because the climate may not be conducive for the proper functioning of the machines.



Source: Moroney (2003)

Fig. 10 Combine harvester

8.2 FUTURE CHALLENGES FOR MACHINE USAGE

The most significant challenges for the future lead to the question, can contractors continue to survive where costs rise and returns from farm remain static? Efficient silage making systems are vital for the future viability of contracting. The output target is now 10 hectares (25 acres) per hour, which can only be achieved at higher harvester forward speeds (Moroney, 2003).

Can farmers continue to embark on heavy implements for land clearing and management? What about the consequences of the use of heavy machines? On the other hand, would the growing population allow the absence of machines? Then, what will be the faith of consumers? Looking at the use of machines, it has both advantages and disadvantages. What can be done to overcome this situation? It is recommended that farm machines be continuously used on farms having considered the trend of food demand and the advantages of using modern equipment. In addition the use of farm

machines out has led to increased in agricultural production. It has also affected the environment causing hardpans and environmental pollution. Despite the disadvantages of farm machines, its use in agriculture can never be neglected.



Source: Moroney (2003)

Fig. 11 Harvester

Advantages of Mechanization

1. Developing new land by clearing obstructions, drainage of water-logged land and levelling of land
2. Reclaiming abandoned land
3. Improving untimely field operations and creating measures for the well-being of families of farmers
4. Reducing spoilage and wastage of crops on the farm
5. Playing a role in preservation and processing of agricultural products
6. Facilitating production to relieve pressure on the markets

8.3 PROBLEMS OF MECHANIZATION IN WEST AFRICAN COUNTRIES

1. Fragmented land holdings
2. Agronomy practices such as cropping systems
3. Lack of maintenance facilities for farm machines
4. Lack of well-trained personnel
5. Poor credit facilities for farmers
6. Lack of sufficient environmental data and information on the suitability for different equipments
7. Labour supply
8. Inadequate infrastructural facilities
9. Inadequate education on the use of machines by local communities

How to Develop Agricultural Mechanization

Agricultural mechanization can be developed when all the factors contributing to the success or failure of mechanization systems are identified. Each of the factors must be given due consideration. The inability to figure out these factors will have a great hindrance on food production. Introduction of farm powers and machinery requires a growing desire by farmers to use better machinery and tools. There should be government interest in agriculture with a better understanding on agricultural development and effective educational research and extension programmes.

Plant Propagation

9

Chapter

9.1 INTRODUCTION

Plant propagation is the increase of plant species either through sexual (from seeds) or asexual (budding, grafting, cutting, layering, runners or rhizome). It promotes the growth of plant tissue into small plantlets. Plant tissue can be extracted from a parent plant and placed within sealed vessels and grown heterotrophically. As soon as the plant material has developed, the capability to photosynthesize the sealed vessels can be transferred to either the main field or a greenhouse environment for photoautotrophic growth.

In crop production, the goal of producers or farmers is usually to propagate a species which produces a product that is valuable to people or society. Propagation of crops may be achieved either by sexual or asexual means. Sexual propagation involves the union of separate male and female gametes through seed cultivation.

9.2 KNOWLEDGE OF PROPAGATION

The propagation of plants is both a science and art. Science of propagation requires the knowledge of plant physiology, nursery cultural practices, and characteristics of the plant intended to be grown and propagated. Propagation practices cannot be taught in the classroom, hence practically demonstrated in the field. The propagation of plants requires a specific technical knowledge that requires practical skills. The propagation of plants requires planning and organizing for successful management. Crop planning is very crucial in plant propagation, yet it is not given proper attention. It is very necessary for a plant breeder to know the appropriate propagation method to be used on a specific crop and when the process should be carried out.

However, plants can be propagated by using seeds or vegetative parts. In propagation plans, breeding the amount of genetic variability that is desired in the crop must be known and considered by the breeder.

9.3 SEED PROPAGATION

Several methods are involved in growing plants from seeds. Direct seeding is described as the traditional method involves placing seeds directly into a container or seedbed that later germinates in place. Seedlings can also be allowed to grow to a certain size and then be transplanted to a larger container. Seeds can also be sown into shallow trays, keeping them moist, and then the germinating seeds can be hand sown into a seed tray or nursery bed. The emerged young plants are later transplanted into containers to complete their development.

In sexual propagation, seeds are produced in a flower. The formation of a seed is a complex process involving a number of steps. Sexual propagation of crops involves sexual reproductive structures known as flowers (Fig. 12). The stem bearing the flower is called the pedicel. The tip of the pedicel, which bears the floral organs is called the **receptacle**.

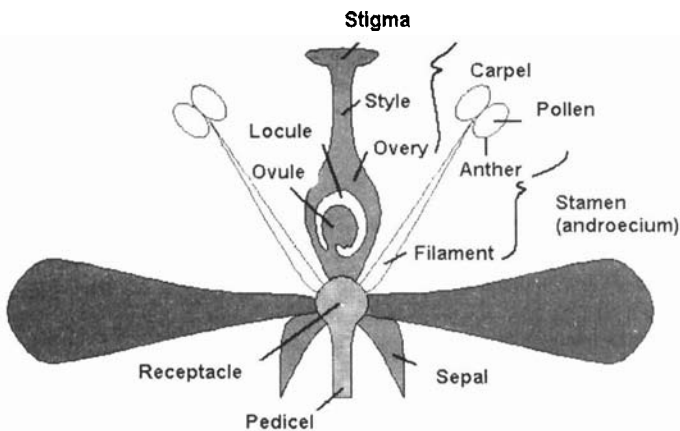


Fig. 12 Structure of flowers

In the centre of the receptacle, there may be one or more organs called **carpels**. Usually each carpel has on the base an enlarged rounded portion called the **ovary**. This is the female organ of the flower. The ovary contains small structures called **ovules**. The ovule contains a single female gamete or egg. Above the ovary is a stalk-like structure known as the **style**. On top of the style is a sticky part with an enlarged region called the **stigma**. Pollen grains usually stick to this region which later fertilizes in the ovule.

Around the carpels are arranged the **stamens (male structure)**. This part produces pollen grains (male gametes). Each stamen consists of a slender stalk called the **filament**. On top of the filament is the **anther** which contains the pollen grains.

In practical crop production, the production of seed is often the goal. The seed may be used to propagate the crop or may be used for consumption by humans and/or livestock. In any case, the seed quality is of prime concern to the crop producer.

9.4 VEGETATIVE PROPAGATION

Asexual reproduction involves the use of vegetative parts (known as vegetative propagation or reproduction). In vegetative propagation, desirable crops are mainly used by farmers for multiplying, by using vegetative organs of other plants like roots or stems.

The objective of vegetative propagation is to make multiple prototypes of individual plants with identical genetic composition. This process involves collecting stem, roots, leaves shoots sections, treating the lower part with rooting hormones, and then sticking them in trays filled with growing medium until they form roots (USDA, 1999).

Some crop plants have horizontally growing stems or roots, which naturally form daughter plants at some distance from the original parent. Examples of these plants include strawberry, ginger plant, sweet potato, Commelina. These plants produce horizontal stems called **stolons**, they are also known as runners. The tip of each stolon usually becomes the upright shoot of the daughter plant.

Some plants like couch grass produce underground horizontal stems called rhizomes. The apical bud at the tip of the rhizome or any axillary bud along its length is capable of growing into an aerial shoot with its own adventitious root system. This, however, may provide some advantage for crop producers and may also be disadvantageous if farmers combat a weed that is propagated by rhizomes.

Some ornamental crops, such as crocus and gladiolus form **corms**. These are swollen stem bases. A corm acts as a region of food storage and also acts as the reproductive structure in plants. They usually contain undeveloped vegetative and floral buds. Corms produce side-shoots, which in turn form small corms known as offsets that are easily separated from the main shoot.

Other methods include grafting, budding, layering, cutting, sucker and runner. Grafting is referred to as a very specialized technique in which the shoots or buds from one plant are surgically implanted into another plant of the same species. The most recent and rapidly developing vegetative propagation technique is the micropropagation. This method involves a series of sterile laboratory techniques that involve small sections of plant tissue which are chemically stimulated to form multiple shoots, and are then rooted (USDA, 1999).

Vegetable Production

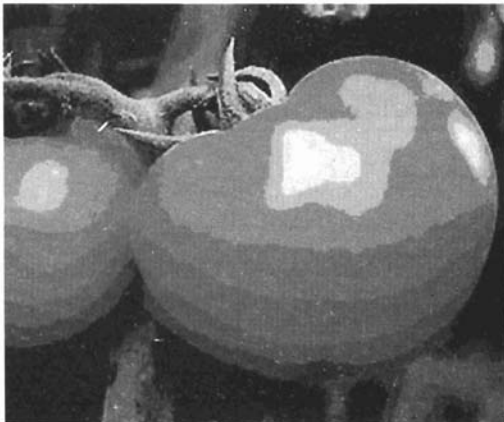
10

Chapter

10.1 TOMATOES

Tomato is one of the most commonly grown fresh vegetables in the market. Tomatoes are high yielding and labour intensive crops. In Massachusetts, for example, there are approximately 500 acres of tomatoes, and approximately 500 vegetable farms. However, some of the larger farms produce are about 10-15 acres in the region of Massachusetts. Although few farmers grow less than one acre (Kuepper and Born, 1999), tomato yields of 650 to 850 boxes (30 pounds each) per acre are common in the South Central U.S. (e.g., Oklahoma) (Dean et al., 1987a). This is equivalent to 19,000 to 25,000 pounds or about 10 to 13 tons per acre (George and Born, 1999).

Production and marketing costs for intensively cultured tomatoes can be over \$4,000 per acre with an expected gross return of \$4,000 to \$8,000 per acre (Dean et al., 1987b).



Source: Hanson et al. (2001)

Commercial tomato production requires a high level of management, labour intensive and high capital inputs as well as close attention to detail. Tomato production is subject to the variations that occur in weather conditions, which may result in severe crop damages and losses. Labour requirements for tomato production, harvesting, grading, packaging and transporting are very intense.

As a warm season crop, its production is simple but very difficult to handle. With special production practices, farmers can produce the first tomatoes within 60 days of cultivation. The crop can be grown for production from June through November by choosing the right varieties and production practices. Generally, tomatoes require a large investment in time and labour, but increase in intensity of management is repaid by increased yields and profits (Sanders, 2001).

Varieties

Variety selection often takes several months before planting. This is one of the most important management decisions made by growers. Failure to select the most suitable varieties may lead to loss of yield and market acceptability. The variety selected should have the potential to produce crops at least equivalent to varieties already grown (Hochmuth et al, 1999).

There are many good tomato varieties that can thrive well in different locations. The choice of varieties is important to farmers, as well as earliness, shipping quality, and disease resistance. The varieties include *Flora Dade*, *Sunpride*, *Colonial*, *Royal Flush*, *Mountain Fresh*, *Mountain Pride* and *Piedmont*.

10.1.1 Soil Conditions

Select a well-drained soil with high organic matter. Test the soil for fertilizer, lime requirements and nematodes. A pH of 6.5 is best. If a nematode test is not done, use a fumigant type. With the selection of soil and a test of nematode, high yield could be achieved.

10.1.2 Fertilization

Tomatoes use a lot of fertilizer. If the soil is not tested, apply 400 to 600 lbs per acre of 10-20-20 in the coastal plain. In the piedmont variety more phosphate will be needed. Coastal plain soils may not need much phosphate, half the fertilizer should be broadcast and the remaining banded 6 inches on either side of the row and 4 inches deep before transplanting. Side-dress with 150 to 250 lbs per acre of 14-0-14 or 15-0-14 just after the first blooms three weeks later, sandy soil may require 13-0-44 and/or a third side dressing (Sanders, 2001) for efficient growth and development.

10.1.3 Transplanting

It is best to grow tomato plants in nurseries and later transplant them to the main garden or field. Shade from sunlight is needed during the nursery stage and thereafter. If this is not feasible, obtain plants from a certified plant grower. Transplant as soon as the danger of frost has passed or use sprinkler irrigation for frost protection. For early production, use plants that have been grown in three to four inch containers (Sanders, 2001).

Water young plants with a starter solution. This is particularly important if bare-rooted plants are used. Commercial water soluble fertilizers are available everywhere. Apply one cup of this solution per plant.

10.1.4 Spacing

Tomato spacing depends on the variety intended to be grown, the training system, and the spray equipment. Determinate plants are usually spaced between 10 cm by 10 cm apart in seed trays.

10.1.5 Weed Control

The control of weeds is very necessary in tomato plots. Several good herbicides are available for applications when practising conventional farming. Currently, new systems of weed control have been developed without the use of chemicals. The method of weed control, as explained in this book will be very useful in tomato weed control.

10.1.6 Plastic Mulch

Black plastic mulch speeds maturity and increases yield. Methyl bromide can be used in conjunction with plastic mulch. If plastic mulch is used, all fertilizers should be mixed in the soil prior to laying the plastic. If plastic is used, drip irrigation will increase yields. Also, fertilizers help increase yield (Sanders, 2001), but this use of fertilizer is not very ideal in production as it has some adverse effects on human health and our environment.

10.1.7 Staking and Pruning

Plants should be staked or trellised. For staking, drive a stake by every other plant leaving at least four feet of the stake above the soil level in order to support tomato stems as they usually possess weak stems. Use plastic twine to form a support on both sides of the plant. The twine should be wrapped around each stake. Remove all suckers up to the one just below the first fruiting hand. Remove suckers when they are small. Tomatoes can also be grown without staking, but the yields will be reduced. It is, therefore, advisable to provide a stake for tomato stems if higher yields are expected.

10.1.8 Irrigation

Crop production in both greenhouse and field has been increasing rapidly. However, technologies for environment, especially soil moisture, management of greenhouse and field is still in the stage of infancy (Lee and Shin, 1998).

Tomatoes need 1 to 1.5 inches of water per week either by rain or irrigation. A uniform water supply reduces blossom-end rot and results in higher yields and better quality (Sanders, 2001). If drip irrigation is used, it should be applied daily and the water should always be applied uniformly in the morning and evening for proper use.

10.1.9 Insect Control

It is necessary to watch out for flea beetles, aphids, Colorado potato beetles, spider mites, and fruit worms. These are the major tomato insects that reduce their yields. Hand-picking is possible on small planting for these insects but becomes impractical for large gardens.

10.1.10 Disease Control

Weeding and good sanitation are essential for disease control. Failure to prevent weeds will result in disease outbreak. The major tomato diseases are blight, grey leaf spot and other foliage diseases. Conventional farmers spray their field as soon as the first flowers appear. It is best to remove weed in tomato plots by mechanical means and hand pulling.

10.1.11 Harvesting and Packaging

Harvesting is usually done by hand picking and the fruits are taken to the market as soon as they are harvested. When shipping to distant markets, fruits should be harvested when still green. For local markets, the fruit should be allowed to develop a yellowish or reddish colour. Packaging should be done in compact containers to avoid damage (Sanders, 2001).

Table 7 Harvesting and packaging

Tomato Size	Diameter (Inches)	Inches
Jumbo	4 × 5	3 × 3 10/16
Extra Large	5 × 5	2 14/16 × 3 6/16
Large	5 × 6	2 11/16 × 3 3/16
Medium	6 × 6	2 8/16 × 2 14/16
Small	6 × 7	2 4/16 × 2 10/16

Source: Sanders (2001)

Successful Production and Marketing Recommendation

To be successful with fresh market tomato production, farmers should select a good variety, preserve seeds for the next season and depend on their own seeds; this will enable farmers monitor the genetic potential from the first general to the last general, if existing. Soil should be tested before cultivation; absence of this will not give farmers the exact composition of the soil being cultivated. Proper ratios of lime and organic fertilizers, fumigates for nematodes or use resistant variety are appropriate.

For successful tomato production, the following points should be taken into consideration:

- Farmers should identify their own markets before planting the first seed
- Use good varieties that are necessary in the location of farms
- Soil should be tested for fertilizers and nematicides
- Use large container transplants for early production
- There should be appropriate weed control
- Prune early and string when needed
- Irrigate to control cracking and blossom end rot
- Pack uniform size and colour fruit

10.2 CARROTS

Carrots (*Daucus carota*) grow well in Saskatchewan's climate and soils. The taproot is the edible portion of the carrot; the foliage has no economic value.

10.2.1 Soil Conditions

Carrots favour well-drained and fine textured soils with good water-holding capacity. Sandy, loamy or muck-based soils are suitable for carrot production. A pH range of 5.5 to 8.0 is desirable. Carrot seedlings are very weak, and cannot tolerate soil crusting. Seedbed preparation must eliminate clouds as they interfere with uniform growth of the roots. Since the taproot is the edible portion of the plant, the field should be tilled to a 30 cm (12 inches) depth to ensure that root penetration is not restricted. Crusting of the soil surface will prevent the seedlings from emerging. For this reason, clay soils should be avoided (Waterer, 2005).

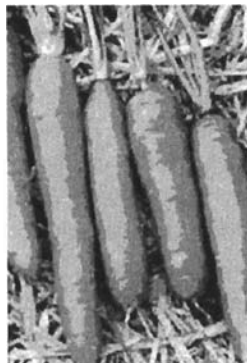
Raised beds are very popular in carrot production as they help the soil warm up faster in the spring, promoting faster emergence of seedlings. The soil tends to be very soft in the beds, which is crucial for weaker carrot seedlings (Waterer, 2005).

10.2.2 Varieties

There are four main types of carrots:

Nantes

This is a popular variety with a sweet taste. Nantes carrots are almost cylindrical in shape, and rounded off at the end rather than tapered. They have a small core and a larger outer cortex. Sugars accumulate in the cortex, giving Nantes their sweet taste. Nantes carrots cannot be stored for very long. They mature in early to mid-summer, and are usually eaten fresh (Waterer, 2005).



Imperator

This carrot type is most commonly grown because of its high yields and long storage potential. Imperators are long and tapered. They are a late-maturing variety, and generally have a larger, more fibrous core; therefore, they do not have the sweet taste of other carrot types.

Chantenay

Shape-wise, Chantenay is an intermediate between a Nantes and an Imperator. They are tapered like the Imperator, but the bottom rounds off somewhat like the Nantes. Chantenays are also sweet tasting like the Nantes.



Danvers

Danvers is medium-length carrots, conical in shape, and thicker than Imperators. The end of the root is tapered. Danvers varieties are used in both processing and commercial fresh market industries.

10.2.3 Seeding

Carrots should be planted early May to mid-May. Seeding rates will depend on carrot type, the variety and the size of the root. General seeding rates are: 10 to 16 plants per 30 cm (12 inches) row for Nantes varieties; and 12 to 18 plants per 30 cm (12 inches) row for Imperator varieties. Higher carrot densities will give a higher total yield, but decreases the average carrot sizes.

Row spacing can vary depending on equipment and planting practices. If planting in raised beds, the beds should be at least four inches off the ground

on 51 to 102 cm (20 to 40 inches) centres. If planting in rows, inter-row spacing ranges from 41 to 76 cm (16 to 30 inches). Inter-row space is also dependant upon the row space capabilities of the tillage equipments and carrot harvester (Waterer, 2005).

Carrot seeds are small, and should be planted 1.9 to 2.5 cm ($\frac{3}{4}$ inch to one inch) deep. Planting any deeper will slow emergence. Stanhay-type belt seeders are known to be the most popular for carrots.

10.2.4 Fertility

Random soil samples should be collected from the entire field where carrots are intended to be planted. Due to climatic conditions and the response of carrots to fertility, differing cultural practices, varying soil conditions and other situations may vary from region to region.

Carrots require 80 kg/ha (71 lbs/ac) of nitrogen on muck soils, and 110 kg/ha (98 lbs/ac) of nitrogen on mineral soils. Phosphorus and potassium will be required in 120 kg/ha and 250 kg/ha (107 lbs/ac and 223 lbs/ac) amounts, respectively. Fertilizer rates should be based on a soil test (Waterer, 2005), which is very necessary.

Over-application of nitrogen on a carrot plot may lead to excess top-growth, which will slow down growth rate and development of the edible taproot.

10.2.5 Irrigation

Adequate amounts of water and proper timing are very critical in carrot production. Carrots do not respond well to inadequate water in soil, particularly in high temperature. Moisture is considered crucial for germination and root development. Watering at germination helps prevent soil crusting, which retards growth of new seedlings.

Carrots require approximately 2.5 cm of water per week. Lack of water or inconsistent watering will no doubt lead to woody flavoured carrots and irregular growth patterns.

10.2.6 Harvesting

Carrots are harvested when they reach the appropriate size. Sweetness and storage potential increase with maturity. Wounding of carrots during harvest should be avoided to reduce the incidence of *sclerotinia* in storage. Carrots are harvested either by cutting off the tops, called topping, and using a digger to lift the carrots, or by using a machine to pull out the carrots by the tops, and then topping them in the field (Waterer, 2005).

Topping usually occurs in the field, when most of the foliage is chopped off, with only 2.5 cm to 5 cm of the stem remaining. The rest of the stem is usually trimmed off prior to packaging (Waterer, 2005). Cool temperature during harvest reduces the amount of field heat that needs to be removed from the carrots when in storage.

Carrots do better in cooler weather than hotter weather, but withstand freezing temperatures. Carrots, if frozen, will have ice crystals on the outside of the root. Allow the carrot to thaw before attempting to harvest. Excessive freezing will show the following symptoms: splitting of root, water-soaked appearance, and flabby or watery breakdown. Carrots exhibiting these symptoms should be discarded.

10.2.7 Storage

Field heat should be removed from carrots as soon as possible after harvest. If possible, harvest the crop close to 0°C (32°F). In the storage room, it should be kept at 0°C (32°F) and 100% relative humidity to ensure minimal moisture loss. Appropriate temperature can store carrots for about six to nine months.

Carrots should be cleaned and washed when in storage. During the cleaning process, any damaged or diseased carrots should be discarded. Conventional farmers use copper sulphate to clean carrots in the storage room which kill any disease organisms which may invade the vegetable.

10.2.8 Problems of Production and Storage

Disease: Aster Yellows

This is usually caused by phytoplasma (virus-like disease) spread by the aster leafhopper (*Macrostelus quadrilineatus*). Not all aster leafhoppers carry the pathogen (Waterer, 2005). Carrots should not be planted near fields in which forage legumes or weeds grow. Many perennial crops host medicinal species, like Echinacea, which are potential hosts for aster yellows. Symptoms of aster yellows include witches' broom appearance to the foliage which first turns yellowish and subsequently bronze in colour, lateral growth, and hairy roots from taproot. Aster yellows are difficult to control because the cost of insecticide is often greater than the economic damage incurred. A constant influx of aster leafhoppers will lead to the need for continued application of insecticides, when necessary (Waterer, 2005).

Sclerotinia

Sclerotinia is a very serious disease of carrots both in the fields and in storage rooms. Symptoms include foliage that is dark brown and coated

with a whitish mould. Subsequently, black dots (sclerotia) appear amid white mould (mycelium). White mould covers the infected carrot, and the black sclerotia follows. Control of sclerotinia begins with crop rotation and careful handling as carrots are harvested and put into storage. The storage units should be disinfected with a 2% solution of copper sulphate.

Weed Management in Vegetable Farms

Weed management is one of the most challenging aspects in both conventional and organic vegetable production, even with rigorous crop rotation (Kent et al., 2001). Yield losses from weeds and the effectiveness of control measures depend largely upon the weed species present. Factors which affect the composition of the weed flora include landscape position, water control, soil fertility, season, rotations and herbicide use (Moody, 1996). A shift in weed populations with changing cultivation practices is thus a predictable consequence of intensification (Mortimer, 1990). The studies on cropping intensification in West Africa considered the influence of reduced fallow periods on weed populations in upland crops (Nyoka, 1982; Moody, 1982; Becker and Johnson, 2001a). The distribution of weed species was considered in relation to management and environmental factors using multivariate techniques. From the perspective of other researchers, cultural practices limit weed pressure. Composting of manure, use of black plastic mulch, and cover cropping with smother crops are cultural practices that limit weed growth. Organic farmers should be acquainted with mechanical methods of weed control. Failure to cultivate effectively results in reduced crop yield, increased hand labour costs, or both. Just as a single herbicide or two cannot provide effective weed control, one or two cultivation implements can rarely provide satisfactory weed control. All farmers should take the control of weeds as a yardstick.

The economics of organic vegetable production is difficult to assess fairly, because of the value of certain indirect benefits, like soil structure improvement, or a reduction in risks associated with pesticide use. Poor quality of crop is sometimes caused by weed outbreak on the farms. For a higher production of crop in any farm enterprise, farmers must effectively control the spread of weeds. Conventional farmers using herbicides to control weed should understand the principles of weed control and methods of application.

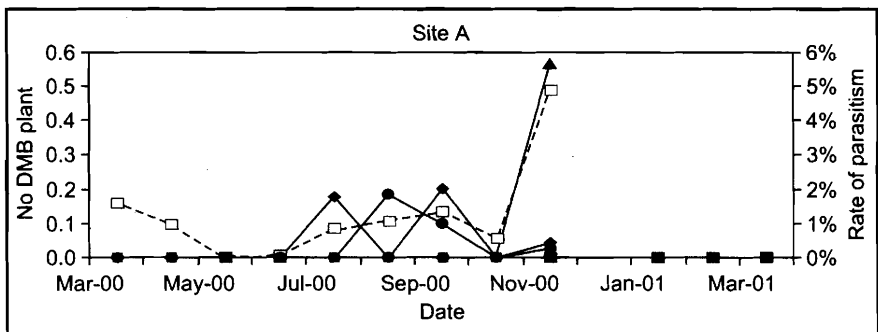
Seasonal Rates of Parasitism in Vegetable Production/Cabbage

An annual cropping system varies in time, both within a season and across seasons, and in space, on local and regional scales. In agro-ecosystems, this is known to have a major effect on the evolution and population dynamics of

pest species (Kennedy and Storer, 2000) and also their natural enemies (Landis et al., 2000). *Plutella xylostella* is a useful model pest that causes damage in cruciferous crops in most parts of the world (Shelton et al., 1996; Ivey and Johnson, 1998). This has been facilitated by continuous planting of crucifers, which allow continuous reproduction of diamondback moth (Talekar and Shelton, 1993). It has been recorded that there is a shortage of effective natural enemies of diamondback moth due to agricultural management practices (Lim, 1986) such as use of pesticides. Talekar and Shelton (1993) suggested that research should be carried out on the survival ability of diamondback moth and its rates of parasitism in a non-continuous cropping environment, to provide more insight into its agro-ecology.

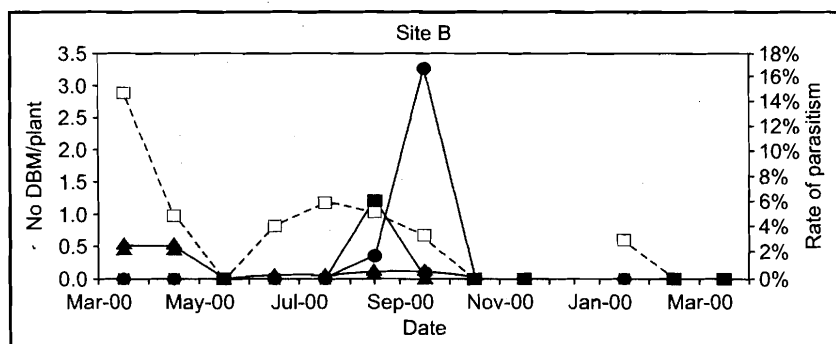
Experimental work conducted in a continuous, commercial cabbage-growing area near Grahamstown in South Africa showed that parasitism of diamondback moth averaged over 60% and could reach 100%. In many parts of the world, cabbage crops are not under continuous cultivation, and periodic cropping systems may demonstrate different patterns of parasitism, especially in disrupted, patchy subsistence crops (Mkize and Villet, 2001). Cabbage (*Brassica oleracea*) is the most commonly grown cruciferous crop in subsistence gardens in the suburbs of Grahamstown East (Mkize and Villet, 2001). The subsistence farmers' crops are considered patchy because the cabbages are grown in small and relatively widely separated plots (Mkize and Villet, 2001). Talekar and Shelton (1993) suggested that investigation be conducted on the population dynamics of *P. xylostella* and its rate of parasitism on cabbage of subsistence farmers where commercial pesticides are used less.

The experiment conducted on *P. xylostella* and its rate of parasitism on cabbage shows that environmental disturbance contributes to its outbreak. Four species of DBM parasitoids were found in the area where the study took place - sites (Figs. 13 and 14 parasitism on cabbage).



Source: Mkize and Villet (2001)

Fig. 13



Source: Mkize and Villet (2001)

Fig. 14

Fig. 13 and 14: Number of plutella (DBM) and percentage parasitism on cabbage of substance farmers at Grialams-town 2000/2001.

These include wasps *Cotesia plutellae* (Kurdjumov, Braconidae), *Diadromus collaris* (Gravenhorst, Ichneumonidae), *Oomyzus sokolowskii* (Kurdjumov, Eulophidae) and *Diadegma mollipla* (Holmgren, Ichneumonidae) (Mkize and Villet, 2001). It was observed that there were distinct differences in the rate of parasitism by the four species discovered (Figs. 7 and 8). In site A, from June to October there was co-existence between *C. plutellae* and *O. sokolowskii* and both species reached the maximum average rates of parasitism of 2%. The decrease in parasitism by *C. plutellae* and the increase of parasitism by *O. sokolowskii* could be due to the fact that *O. sokolowskii* was seen to be facultative hyperparasitoid of *C. plutellae* (Talekar, 1996). Parasitism by *D. mollipla* at site B averaged 6%, whereas in site A it was negligible (Mkize and Villet, 2001). In site B, the monthly average levels of parasitism by *O. sokolowskii* peaked at 17.9%. The availability of parasitoids was due to the availability of flowers, because nectar sources increase their longevity and fecundity (Idris and Grafius, 1995), but rates of parasitism were still not as high as Smith's (pers. comm.) and temporal arrangement of habitat patches over small scales.

It was concluded that the number of *P. xylostella* and its parasitoids were seen to be affected by the spatial and temporal arrangement of habitat patches over small scales. Smith's work also showed that parasitism of diamondback moth can reach higher levels in a continuous commercial cabbage-growing environment where *P. xylostella* is common.

10.3 CULTIVATION OF ONIONS (*Allium cepa*)

Onion is a popular vegetable grown for its pungent bulbs and flavourful leaves. It is widely cultivated all over the world and its bulb is composed of

concentric, fleshy, enlarged leaf bases or scales. Its outer leaf bases lose moisture and become scaly and the inner leaves generally thicken as the bulb develops (Shanmugasundaram, 2001).

The green leaves above the bulb are cylindrical and hollow, and arise sequentially from the meristem at the innermost point at the base of the bulb. The stem is very small and insignificant during vegetative growth. After vernalization at temperatures below 10°C, the stem elongates rapidly, eventually producing compound umbels. Bolting has been reported to be related to the length of day. However, long days do not induce reproductive growth but tend to accelerate development of the seed stalk once it has been initiated by vernalization. Temperature has a major role in inducing bolting (Shanmugasundaram, 2001).

Onion root system is fibrous, which spreads beneath the soil surface to a distance of 30 to 46 cm. There are a few laterals and the total root growth is sparse and not aggressive. In monoculture, onions tolerate crowding, particularly in loose, friable soils like peat. Competition from aggressive root systems limits onion growth in many parts of the world. Temperature may interact with its day-length growth and modifies the bulb. In all cultivars, bulbing is accelerated with increasing temperature. Extreme temperature affects the rate of bulbing and the bulb shape.

10.3.1 Cultivars

All onion cultivars were open-pollinated simultaneously, and many of these cultivars are still offered by seed companies (Shanmugasundaram, 2001). The discovery of male sterility in onion led to a rapid change to F1 hybrids, possibly due to simplicity and low cost of seed production (Shanmugasundaram, 2001). Male sterility is a genic-cytoplasmic factor, and male fertility can be restored in plants carrying the sterility factor by introducing a single dominant allele (Shanmugasundaram, 2001). Any line carrying the sterile trait must be cross-pollinated, and seeds harvested from male sterile plants isolated with a normal pollen-bearing parent will be a hybrid seed. Hybrids have higher yield, larger and more uniform bulb sizes than open-pollinated cultivars (Shanmugasundaram, 2001). The bulb onion cultivars are grouped into short, intermediate, and long-day types. Short-day onions (12 to 13 hours threshold) are generally mild, soft fleshed, and suitable for storage.

10.3.2 Climatic and Soil Requirements

Onions can grow successfully on any fertile, well-drained and non-crusting soil. The optimum pH range, regardless of soil type, varies between 6.0 and

6.8. Alkaline soils are also suitable for the growth of this vegetable. This crop does not perform well on a soil below pH 6.0 due to deficiency of trace elements and aluminium or manganese toxicity. Onion is a cool-season biennial crop which is tolerant to frost. The optimum temperature required for development is between 13 and 24°C. However, high temperature favours bulbing and curing.

10.3.3 Planting Systems

There are three systems involved in planting onions:

1. Direct seedling, which gives excellent results where the season is sufficiently long to provide early prebulbing growth.
2. Transplants, which normally involve three to five well formed plants. Transplant leaves are pruned during growth prior to field setting, which facilitates handling and increasing the hardiness.
3. Sets are used to ensure large bulb size and uniform maturity. Sets are small dry bulbs of approximately 12 mm in diameter.

10.3.4 Nutrient Management

Onion responds very well to organic manure. Organic manure at 25 to 40 t/ha is recommended to obtain high bulb yield (Shanmugasundaram, 2001).

Fertilizer is applied either as a broadcast, or more commonly as a band, 5 to 10 cm directly below the seed set or transplant. Onion plants utilize substantial amounts of nutrients. Based on a yield of 18 t/ha of bulbs, the plants remove an average of 66, 11, and 70 kg of N, P, and K respectively. Soils differ widely in fertilizer needs, depending on production history, soil type, and analysis (Shanmugasundaram, 2001).

90 to 112 kg/ha of N, and 56 to 168 kg/ha of P_2O_5 and N, P, K application of about 160, 90, and 40 kg/ha respectively is ideal for mineral soils. One or two side nitrogen dressings should be applied during one season. Insufficient nitrogen will induce early maturity and reduce bulb size; high N may increase bulb size and may cause large nicks and soft bulbs with poor storage ability.

10.3.5 Water Management

Uniform application of water throughout the growing season is imperative. Fields that suffer growth retardation may produce excessive numbers of doubles or splits, reducing the number of grades in bulb classification. The recommended irrigation practice is furrow. Onions at the bulbing stage use substantial amounts of water, but excess moisture must be avoided during the growing season to avoid problems in production of quality yield.

10.3.6 Weed and Disease Control

There is high weed competition in onions plots. The cultivation must be shallow to avoid root damage. In most cases, producers prefer organic weed control on the plot as a result of high competition. Pre-emergent broadcast applications of DCPA or one of the several organic compounds have been used for many years for successful control of weeds.

Disease Control

Both field and storage diseases reduce profitability. Field diseases include purple blotch, *Stemphylium* blight, anthracnose, downy mildew, botrytis leaf blight, pink root, smut, smudge, and several basal rots. Storage diseases include some of the common field rots, black mould, botrytis neck rot, and bacterial soft rot (Shanmugasundaram, 2001).

Purple Blotch

This attacks onion, garlic, shallot and other *Allium* crops. Initially, small white sunken spots develop on the leaves. These enlarge, become zonate and under moist conditions, turn purple. These are also prominent on the inflorescence stalks. Infection can cause a semi-watery rot on necks of bulbs that turn yellow-red in colour. Infected bulb tissues eventually become papery. This pathogen is widespread. The optimum temperature for disease development is 21 to 30°C and it is very harmful in hot and humid climates (Shanmugasundaram, 2001).

Cultural control methods include long rotations with unrelated crops and good drainage. Lowering the density of transplanted crops will reduce infection, as well as the application of high rates of calcium superphosphate and potassium fertilizer. Nitrogen fertilizer at low and high rates will increase the prevalence of disease. Routine (weekly interval) field sprays with dithiocarbamate fungicides, particularly mancozeb and chlorothalonil, have been reported to be effective (Shanmugasundaram, 2001).

***Stemphylium* Leaf Blight**

This has been reported from Europe, Africa, North and South America as well as Asia. Foliage losses of 80 to 90% have been reported, based on the results of research carried out by numerous scientists. Disease symptoms are very similar to purple blotch. Lesions are light yellow to brown according to Shanmugasundaram (2001).

Anthracnose

This disease usually develops in hot (24 to 29°C) and damp conditions. The disease is spread by wind, splashing water, farm implements and tools. The leaves become twisted as a result of the attack.

Downy Mildew

This attacks young plants, appearing as white specks, usually confined to the oldest leaves of young plants. A white mould develops rapidly in cool damp weather and progresses down the sheath, as reported by Shanmugasundaram (2001), and plants eventually droop and dry up.

Botrytis Leaf Blight

The disease appears first as white specks on leaves; it later expands to cause a dieback from the leaf tips. The tips may be destroyed completely within some days, and the entire fields may also be affected. Conventional farmers. Control is the disease with mancozeb sprays at approximately seven-day intervals.

Several **bulb rots** may occur either in the field or in storage. **Basal rot**, caused by *Fusarium* species, results in a breakdown of inner scales. Outwardly, the bulb may appear normal. It eventually becomes soft, however, and develops a watery rot under moist conditions or a dry shrivelled bulb in a dry environment. The disease is most severe in warm areas with poor soil drainage. **Botrytis neck rot** is an extension of leaf blight disease and can become serious in storage (Shanmugasundaram, 2001).

Insect Pest Control

Severe infestations result in leaf blasting and collapse. Bulbs become distorted and undersized. Infestations are more severe in dry season than in moist, and entire fields may be destroyed. Insects have many host plants. Adults and nymphs overwinter on plants or plant debris, or in weeds bordering the field. Most of the insects are female which reproduce without a male. Eggs are thrust into the leaves and hatch within five to ten days. Pest control can be done using diazmon spray within seven to ten day intervals in conventional onion plots. Application of spray for about six times during growth will be a successful measure for control in conventional farms. However, the current farming methods do not encourage the use of chemicals in pest control but, crop rotation and hygiene are favoured.

10.3.7 Post-planting Operations

Harvesting

Onions are ready for harvest as soon as the leaves collapse. For storage, onion tops should have broken over before harvest and the necks should collapse and dry. Storage bulb maturity may be accelerated by irrigation water or by pruning the root system. Bulbs for storage may be harvested when 50% or more of the tops have broken over, though the bulbs must be cured and dried thoroughly before being placed in storage. Bulbs intended for immediate use can be undercut when 15 to 25% of the tops are down.

Curing

Curing is done to allow natural dormancy develop and to also dry the onion sufficiently. Properly cured onions will have a dry shrunken neck and dry outer scales. The respiration rate of a cured bulb may be lower than an uncured bulb. Fully mature bulbs are harvested and cured by exposure to temperatures of about 34 to 35°C with less than 50% relative humidity. It is also necessary to provide air movement at a rate of 1 cubic foot/minute/cubic foot of onions (60 cubic meter/hour/cubic meters of onions). Air exchange in the storage facility is important to prevent any condensation on the bulbs.

Storing

Freshly harvested onions are dormant and will not sprout for a variable period of time. Storage prolongs this dormancy. Sprouting increases in storage temperatures above 4.4°C, decreasing again as temperatures exceed 25°C. To reduce the frequency of sprouting after the rest period, onions may be field treated with maleic hydrazide (MH-30) at 2.2 to 3.4 kg/ha when the tops are still green but beginning to senesce.

Bulbs with fleshy, soft necks are susceptible to persistent rot, especially if storage humidity exceeds 70%. Flavour in onion is associated with pungency (propyl disulfides and other disulfides) and with sugars (glucose, fructose, and sucrose). Both sugar content and pungency are related to percentage dry matter. Short-day and long-day types differ in their flavours. Pungency and dry matter content are important quality attributes in onions for processing (Shanmugasundaram, 2001).

10.4 GARDEN EGG PRODUCTION

The aubergine (*Solanum melongena* L.) is one of the most important commercial vegetables in the Mediterranean region and Turkey in

particular. Turkey has about 8533 ha greenhouse area of which more than half is in the Antalya region on the Mediterranean coast and 17% of the total area is used in aubergine production (Kürklü, 1990). Its high temperature requirement is the main factor limiting its growth in Western and Northern Europe. Heating costs are the main input associated with the production of the crop. Thus energy management or energy saving techniques aimed at reducing heat costs will increase the efficiency of crop production.

Young plants are cultivated at a day temperature somewhat higher than the night temperature. Thermoperiodicity term is a term first introduced by Went in 1944 who defined it as "all effects of a temperature differential between light and dark periods of the plant, whether they are flowering, fruiting or growth" (Friend, 1976). If a plant shows increased growth under alternating day and night temperature conditions compared with constant temperature conditions. The plant is said to show thermoperiodicity. However, it is indicated that literature on growth responses to temperature is confused and sometimes contradictory (Ellis et al., 1988); for instance, a close re-examination of original data of Went (1944) shows some evidence for thermoperiodicity. Although, Went (1969) showed some evidence for optimal thermoperiodicity in stem elongation, flower initiation, and other developmental aspects of growth, there has been little experimental support for the existence of optimal thermoperiodicity in terms of total plant weight.

Garden egg requires a very warm, sheltered sunny position. However, it thrives well in most soils. It requires plenty of moisture during its growth. Soil where aubergines are grown should be well drained and the pH requirement should range between 5.5 and 7.0. Aubergine is often cultivated, especially in tropical areas for its edible fruits; there are many named varieties. It is not frost-hardy and can be grown as an annual plant in temperate zones. The fruit of outdoor grown plants in cooler temperate climates of Europe does not ripen easily.

A steady temperature of 30°C (85°F) is necessary during the growing season for the best production of flowers and fruits. The plants should be restricted to not more than four fruits to make sure they reach a good size and ripen properly.

10.4.1 Cultural Practices

A standard aubergine plant produces fruits with egg shape, glossy, purple-black of 6 to 9 inches (15 cm to 20 cm) long. The long, slender, Japanese aubergine has a thinner skin and more delicate flavour. Both varieties grow well in containers. Warm to hot weather throughout the season is necessary for good production (Kawerau, 2005).

The seeds germinate quickly at 21° to 32° (70° to 90°F;) and the plants should be grown for about eight to ten weeks before setting them out. Cold temperature will stop plant and root growth, reducing plant vigour and yield. Hot caps or cloches should be used to protect plants from cold conditions.

Aubergines thrive well in hot weather; well-drained soil should be provided to enable them flourish very well in humid areas. When plants are about 6 inches high, nip back the growing tip in order to encourage branching. Fruits should be collected when immature at about two thirds maximum size. Mature fruit should not be left on the plant, as it may reduce overall productivity.

10.4.2 Climatic and Soil Requirements

Aubergine is a very tender plant that requires a long, warm season for successful production. The plants are destroyed by light frost and are injured by long periods of chilly, frostless weather (Kawerau, 2005). Aubergine should not be set out until danger of all frost has passed.

Soil Requirements

Aubergine grow well in a well-drained sandy loam or loam soil that is fairly high in organic matter content. Aubergines need warm soil and warm temperatures. The required temperature should remain above 20°C (68°F).



Heavy feeders should be planted in heavily composted soil with lots of manure, if available; side dress frequently, especially when the plant begins to bloom (Kawerau, 2005). It is drought tolerant and should not be overwatered as it may lead to root rot. Provision of mulch around aubergine plant helps reduce the rate of moisture.

Water Requirements

Eggplant should be watered sufficiently to moisten the soil to a depth of a minimum 6 inches (15 cm). The critical period for moisture occurs during fruit development. Mulching can help provide uniform amount of moisture at this stage. Moderate water per week in sandy soil is appropriate.

Fertilizer Requirements

Lime and fertilizer applications are best based on a soil test. In general, 1.0 kg each of actual nitrogen, phosphorus (P_2O_5), and potash (K_2O) per 1,000 square 300 m² of garden space is adequate (Kawerau, 2005).

Application of 0.5 kg of nitrogen per 1,000 sq. ft. (300 m²) after the fruit appears, may be helpful to maintain plant development.

10.4.3 Planting

Planting should be done after the soil has warmed up and all dangers of frost have passed. Seeds should be grown indoors at least eight weeks before transplanting period. Cold soil will shock the plant and set it back several weeks. In case of an unexpected late frost, cover young plants with hotcaps or milk jugs to warm it up before transplanting period. It performs better in green houses than in the field.



Eggplant does not require much fertilizer, a spoonful is enough to support the plant growth. Re-fertilization is necessary when buds or tiny Aubergines appear, but it should be kept light. They are suitable for growing in large containers or tubs. Container growing will help prevent soil-borne diseases.

Transplanting

Transplanting should start early indoors in peat pots or cell packs. Rows should be 3 to 5 ft (1 m to 1.8 m) apart. Plants should be 2 to 3 ft (0.7 m to 1 m) apart. Transplants should be 8 to 10 weeks old and slightly hardened, grown in 2 inch (5 cm) or larger pots (Kawerau, 2005).

The outdoor environment can be very harsh for a transplant. Harden the transplants before planting to increase their survival rate. They should be placed outdoors in their original containers so that they receive direct sunlight and some wind for a few hours each day for a week, or possibly more. The duration of time outside each day should be gradually increased. The plants should be moved inside at night (Kawerau, 2005).

Kawerau (2005) suggested that when frost danger has passed and the soil has warmed up, the plants should be transferred to the field. He also suggested that it should be done when the average daily temperature is about 18°C (65°F).

10.4.4 Preplanting Operations

Common Pests and Diseases

Aphids, red spider mites and caterpillars are the main pests. Others include: Colorado potato beetle, tomato russet mite, flea beetle, lace bugs, root-knot,

nematodes, thrips, tomato hornworms, pepper maggot and whitefly (Kawerau, 2005).

Plant Diseases

Phytophthora Blight—Avoid waterlogged root zones.

Aubergines should be grown on well-drained fields. Planting on raised beds will increase soil drainage. Water management is of primary importance for controlling *Phytophthora* blight. Rotate infested fields with other non-host crops for several years (Kawerau, 2005).

Verticillium Wilt—The susceptibility of eggplant to verticillium wilt results in lower yield. The control of this disease is successful through rotation with other crops on the same garden soil. Soil infected with verticillium wilts should be avoided. Soil should be fumigated with propriety soil fumigant—20 to 30 gal. (100 lt to 150 lt) per acre.

10.4.5 Harvesting Aubergine

Fruit vegetables such as eggplants are carefully harvested to avoid damage, after a worker selects mature fruits. The worker estimates empirically the maturity taking account of the growth of the plant, the market tendency, the varietals characteristics and so on. Since it is difficult for conventional agricultural machines to perform such intellectual judgment, the harvesting operation is conducted by hand at present and is not fully mechanized. According to a statistical report, the total number of working hours for eggplant production in Japan is about 200 h/a and the harvesting operation accounts for a little less than 40% (Hayashi et al., 2002). If the development of an intelligent agricultural machine could be extended to complex crop management operations such as training, trimming, etc., a convenient farming system may eventually be developed. Moreover, this could pave the way for the development of new vegetable production systems worldwide.

However, the harvesting operation for eggplants or aubergine is complicated and accounts for a little less than 40% of the total number of working hours. For automating the harvesting operation, an intelligent robot that can emulate the judgment of human labour is necessary. A study conducted on aubergine harvesting was based on developing a robotic harvesting system that performs recognition, approach, and picking tasks (Hayashi et al., 2002). In order to accomplish these tasks, 3 essential components were developed. First, a machine vision algorithm combining a colour segment operation and a vertical dividing operation was developed. The algorithm could detect the fruit even under different light conditions. Next, a visual feedback fuzzy control model to actuate a manipulator was

designed as well. The control model enabled the manipulator end to approach the fruit from a distance of 300 mm (Hayashi et al., 2002). In addition, an end-effector composed of a fruit-grasping mechanism, a size-judging mechanism, and a peduncle-cutting mechanism has also been developed with the intention to assure a successful harvest of the fruits. These machines produced enough force for grasping the fruit and cutting the tough peduncle.

Developing Well Functioning Markets

11

Chapter

Food markets are responding to populations that are becoming increasingly urbanized, earning higher incomes, and demanding more diverse products of higher quality and value. These product include livestock, fruits, vegetables, flowers, and processed foods, as food markets globalize and trade in high-value agricultural products has been growing. Increasingly, organizations engaged in food processing in developed and developing countries are sourcing their supplies globally. If the obstacles to international trade currently faced by the poorer developing countries are subsidies, and tariff such as high taxes and non-tariff trade barriers are eliminated, then agricultural producers will have a greater chance to participate in such trade.

To help the rural poor participate in these local and international markets, agricultural output should be diversified, quality of produce should be improved, and agro-based processing must add value to primary products. These communities could become better organized through cooperatives which could help provide a range of necessary rural facilities. Agricultural research has encouraged the following:

- Support of agro-based processing and rural entrepreneurship
- Strengthening of local market organizations and institutions
- Promoting of agricultural services through cooperatives and rural agricultural education
- Promoting access of farmers in developing countries to international markets

11.1 TREND FOR ORGANIC MARKETS

In 2001, the market study on world markets for organic fruits and vegetables was published by FAO/ITC/CTA. The publication provides detailed information on demand for organic fresh produce in the world's largest

organic markets (United States, Japan and European countries) and gives case studies of seven developing countries that have established an organic export sector or are in the process of doing so.

The European Union market for certified organic fruits and vegetables was estimated to be US\$ 1.7 billion in 2002 according to FoodNews 2003. The organic market has shown a rapid growth in the United Kingdom in the late 1990s, but the present growth is showing a significant difference compared to the previous years over the recent years, the UK sales for organic food and drinks have doubled. Among all fruits, it was recorded that citrus fruits are the most important organic fruit category analyzed so far in the United Kingdom. In classifying fruits, orange surpasses banana as the most consumed organic fruit in the EU. Though no data is available on the sales value of organic fresh citrus fruits. It is, however, estimated that they represent between 5 and 7% of fresh organic fruits and vegetables. According to Hamm et al. (2002), the EU consumed over 350,000 tonnes of fresh certified organic fruits in 2000. Citrus fruits account for 37% of total organic fruit consumption. From these figures, it can be deduced that there is a significant improvement in fresh organic fruits and vegetable consumption. However, a greater quantity is still required to be cultivated to continuously support the growing world population.

A study conducted by Hamm et al. in 2002 revealed that UK is the second largest market for organic citrus fruits in the EU. It was reported that the sale estimate in 2001-2002 was US\$ 1.45 billion. The study also identified that the import of organic fruit into the UK in 2001 was approximately 8,000 tonnes.

The rate of organic consumption in the UK has led to a drastic increase in prices compared to the European countries. The increase in prices is, however, the result of demand for higher quality citrus fruits. In early 2003,

Table 8: UK retail prices for organic fruits and vegetable in pounds (£) and euro (€) in January 2001

<i>Products</i>	<i>Organic</i>		<i>Conventional</i>	
	<i>Prices in £/kg</i>	<i>Prices in €/kg</i>	<i>Prices in £/kg</i>	<i>Prices in €/kg</i>
Sweet potatoes	3,78	5,85	1,89	2,93
Oranges	1,99	3,08	1,44	2,23
Pineapples	1,99	3,08	0,99	1,53
Bananas	1,4	2,17	0,99	1,53
Tomatoes	1,39	2,15	0,99	1,53
Mangos	1,69	2,62	0,99	1,53
Limes	0,59	0,91	0,19	0,29

the price premium was reported to be 25% and above compared to the 15% recorded in 2001-2002.

According to the European Commission (2002), the budget for fruits and vegetables was EUR 1,650 million for 2002 (3.7% of the agricultural budget). Around 56% of this amount was budgeted for fresh fruits and vegetables. The main beneficiaries of 2002 EU spending were Spain (34% of fruit and vegetable expenditure), Italy (22%), France (19%), and Greece (15%).

11.2 FOREIGN TRADE WITH ORGANIC PRODUCTS

In order to export successfully, good and reliable relations with an importer, trader or wholesaler in the target market are important. For export commodities, it is necessary for importers to have an up-to-date information on the latest market developments. As the World Customs Organization does not classify organic products separately, currently there is no foreign trade statistical data on organic products, which makes it impossible to give an overview of international organic trade. There were no official statistics on US imports and exports of organic products before 2002.

Importers of organic foodstuff (fruits and vegetables) are found across the world. It seems that a relatively big share of them are based in the US, especially on the west coast in California and in the northeastern region, mainly the states of New York and New Jersey. They tend to specialize in certain product groups like fruits and vegetables, dried fruit, nuts, etc., which is imperative as the handling and marketing channel would be understood. Some companies have developed organic product lines in addition to their conventional products whereas others have built up their organic business from scratch. Many of these companies are traders and exporters.

To import organic fruits and vegetables into Belgium, Council Regulation (EEC) No. 2092/91 is a prerequisite. However, organic certification is only one of the requirements needed to enter the market. In February 2001, a new project with the title "Bio-theek" was introduced and was coordinated by BioForum, the Belgian umbrella organization for the organic sector. The objective of the project was to collect and disseminate the most recent data available on production, consumption, imports and exports of organic products. However, since the information was not expected to be available before early 2002, what follows in this section is an analysis of imports of organic fruits and vegetables based on interviews with importers and traders. During the analysis, a wide range of uncertainties and other difficulties were faced in sourcing appropriate data.

Although Belgium is a net importer of organic fruits and vegetables, re-exports do exist. In relation to trade flows within the European Community,

especially in the case of the Netherlands and Belgium, many products imported into these countries are re-exported to other European countries. Therefore, organic fruits and vegetables imported into Belgium from the Netherlands (a major supplier to the Belgian organic market for fresh horticultural products) are not necessarily produced in Belgium.

Belgium is the home to a significant number of food processing industries, including organic processors, where fresh fruits and vegetables are processed into canned or frozen products. These industries import large amounts of fresh organic horticultural products. A market survey was carried out in Belgium in late February-early March 2001, a time of the year with typically high imports, due to a lack of local supply. Some market sources provided data based on the weekly amounts traded during the market survey, from which annual totals were derived by multiplying by 52 (weeks).

11.3 PRICES OF ORGANIC FRUITS AND VEGETABLES

From the study on world markets for organic products by FAO/ITC/CTA, it was discovered that a group of consumers are willing to pay a certain premium price for organic foods. In many countries in the world of today, despite the fact that organic products are very expensive, most consumers are still willing to pay 20% more for organic than for conventional products; no precise figures have been obtained on the products that have been bought so far.

Organic sales through supermarkets are the fastest growing distribution channels in most markets. Some market sources stated that consumers buying organic produce from conventional retail channels (e.g., supermarket) differ somewhat from other organic consumers. Environmental considerations are less important when purchasing organic produce. Those purchases by less environmentally conscious consumers lend some support to the expectation of decreasing price premium in the future.

According to the information collected by the World Market for Organic Fruits and Vegetables (2001), the prices on-farm in Germany generally vary considerably for organic fruits and vegetables in different seasons. The wholesale prices for the same product tend to differ less as there is more transparency and competition between the companies and fewer market players. At the retail level, prices differ mostly according to the type of outlet. In a natural food store, the products are often more expensive than in an organic supermarket or in a conventional supermarket that sells organic products. Despite the fact that conventional stores also sell organic products, it is imperative to understand that the supplying countries differ

from country to country. However, as stipulated in the table given below, the prices of fruits and vegetables per kilogram are indicated for each country.

Table 9 Price premium for some organic fruits and vegetables in Germany (2001) imported from the countries listed below

<i>Product</i>	<i>Price of the product in €/kg</i>	<i>Country of origin</i>
Tornatoes	31.50	Italy
Lettuce	13.30	France
Apples	20.00	Germany
Oranges	19.00	Spain
Lemon	18.00	Spain
Bananas	26.95	Dominican Republic

According to the statistical data available in Austria 2001, no specific data was available for the sales of fruits and vegetables, but "Verein der Naturkostläden Österreichs", had to rely on their own assessment and supermarket observations.

Table 10 Average prices at retail level and premiums for the stated organic products

<i>Products</i>	<i>Prices of organic products in €/kg</i>	<i>Premium in percentage</i>
Potatoes	12.90	45
Carrots	10.90	122
Oranges	19.90	33
Apples	24.90	25
Pears	29.90	25

Source: Verein der Naturkostläden Österreichs (supermarkets collection). In Hamm and Gronefeld (2004)

11.4 SUPPLY BALANCE OF ORGANIC VEGETABLES IN 2001

According to Hamm and Gronefeld (2004), it was estimated that the sales of organic vegetables in Denmark in 2001 was 100% (35,540 tonnes). It was also mentioned that about 1,100 tonnes were imported while 1,700 were exported. In Germany, there was a total sale of 95% (184,300 tonnes). The imports accounted for 40,000 tonnes and the export quantity was 10,000 tonnes. The organic vegetable consumption was very high (214,300 tonnes) compared to the production (200,000 tonnes). In Italy, the production

accounted for 156,854 tonnes; the total consumption (144,000 tonnes) was a bit lower than the production. The export in 2001 was 31,000 tonnes, while the imports amounted to 15,000 tonnes. The total sale of organic vegetables was 130,000 tonnes. In the UK, the vegetable production was 56,062 tonnes and consumption was 64,631 tonnes. As the production was lower than the consumption, there was no export; instead they imported 29,000 tonnes. The organic sale was 90% as stated by Hamm and Gronefeld (2004).

The general overview of the total supply balance of organic vegetables production in the European Union in 2001 shows that the total production estimated was 724,447 tonnes of which 5% was used on farm (36,527). The total sales as organic were recorded as 687,930 tonnes while the imported products account for 168,655 tonnes. The total exported product to outside EU countries amounted to 132,923 tonnes and the total consumption of fruits and vegetables was to 690,463 tonnes (Hamm and Gronefeld, 2004).

To have a general overview of the total supply balance of organic vegetable production in the EU in 2001, from the estimated amount by the authors, the record of production in 2001 shows that the total production was 724,447 tonnes, 5% was used on farm 36,527 the total sale as organic was 687,930 tonnes, imports accounted for 168,655 tonnes, while the exported product to outside EU countries was 132,923 tonnes, and the total consumption of fruits and vegetables amounted to 690,463 tonnes.

Table 11 Supply balance of organic fruits (2001)

<i>Country produced</i>	<i>Organic fruit (tonnes)</i>	<i>Sales as organic (tonnes)</i>	<i>Export (tonnes)</i>	<i>Import (tonnes)</i>	<i>Consumption (tonnes)</i>
Denmark	1,019	1,019	20	9,700	10,699
Germany	63,000	54,999	8,000	80,000	126,999
Italy	400,000	304,000	150,000	18,000	172,000
Netherlands	3,700	3,700	58,000	68,100	13,800
United Kingdom	5,422	3,253	1	73,300	76,552

Source: Hamm and Gronefeld (2004)

11.5 CONSUMER HABITS AND PRODUCT PREFERENCES

The marketing of organic fruits and vegetables depends on the strategy of supermarket chains. Although 50-60% of organic products are currently sold in local open-air markets, within the EU states, future sales growth is expected to come mainly from supermarket chains.

Up to this time, supermarket chains have taken different stances toward selling organic produce. Few have so far developed a wide range of organic products. This trend is even more marked for organic fruits and vegetables. Organic fruits and vegetables are usually sold packed in supermarkets in order to distinguish them from conventional fruits and vegetables. This raises the costs and creates problems for many organic producers who are not equipped with packaging facilities.

Organic consumers are always very keen to understand how the products they want to purchase are produced. Quite often, they want to know the country of origin. In producing some fruits and vegetables, the taste of consumers is a yardstick of consideration for consumer preference. In most cases, producers produce the preference of consumers, in order to satisfy their needs. As earlier stated, marketing of organic produce depends on the supermarket strategy and the supermarkets depend on the consumers. This is an important point for consideration in looking at consumers' preferences.

11.6 GENERAL DISCUSSION ON ORGANIC MARKETS

The statistics of France Organic Marketing strategy state very clearly that the growth rate of their organic market is about 12% annually. It was clearly indicated that the recent food safety problems like dioxin contamination and the uncertainty surrounding the safety of genetically modified foods, have raised the demand for organic products. According to a survey by Organic Monitor in 2001, the organic vegetables market was forecast to be growing by more than 30% annually.

Calculations based on present statistics of an industry survey indicated that the combined turnover of organic fruit and vegetable production level increased by 20% between 1999 and 2000. Bio Convergence forecasted that between 1996 and 2002, the markets for organic fruits and vegetables would double. This forecast, materialized at the stipulated time as predicted, due to consumers interest in organic products.

In the case of the US, which is currently the world's largest market for organic fruits and vegetables, industry sources expect a strong growth to continue over a short time. Natural Marketing Institute, in cooperation with Organic Trade Association (OTA), forecasted that retail sales for organic products were going to reach US\$ 20 billion in 2005. This assumption was based on the rate of Organic Consumers' Preferences in 2001. However, the new statistics for the prediction was not yet out prior to the publication of this book.

In further analysis of the prediction, the factors behind it were based on the positive growth expectations and strong increase in consumers' awareness of health and environmental issues associated with organic produce. Another important factor is the increasingly aggressive and targeted marketing and sales promotion by the retail sector, which is likely to be intensified. Organic products are of increasing interest in developing countries as the people are currently aware of the trend for organic products in the world markets.

To enhance and strengthen the awareness of organic products among consumers, magazines in different countries and internet information will be very useful in raising level of awareness, understanding of the current trend and scientific procedures/new products.

11.7 RECOMMENDATION

As it is easier to enter a new market during periods of strong growth, potential exporters should exploit market trends to maximum, in order to secure a strong foothold before competing with others already in the system. A considerable amount of work is necessary to build up an organic export trade in developing countries, both on the production side and on the marketing side. At country level, a good agricultural supply base with appropriate national or international certification is absolutely imperative. While for the producers/exporters, it is equally important to offer a range of high quality organic food products that meet the requirements of the market.

Export products must meet all legal and market requirements (hygiene, weight, size, ripeness, colour, packing, and other technical specifications) of the importing country. Exporters must keep themselves informed of market developments through information sharing, reading trade journals, and the internet. They should visit organic trade fairs regularly.

Developing countries should look at the US, European and Japanese markets not only as a potential future market for organic products, but also consider it as possible partners in various forms of cooperation within farming, processing and marketing of organic fruit and vegetable products. There are a number of individuals, companies and other organizations that are interested in developing export projects in partnership with developing countries. It is advisable that the producers/exporters make contact with partners dealing with organic products for future benefit.

Supermarkets have been identified as the fastest growing sales outlet for organic produce. With the increasing importance of supermarkets as a sales outlet for organic fruits and vegetables in developed countries, supermarkets are increasingly establishing commodity chains in international

organic trade. In general, high requirements for produce to be purchased by foreign supermarket chains can act as a barrier for some organic producers who are not able to meet a standard level of quality. The organic market provides considerable rewards and income guarantees for organic producers who meet the standards and can operate at the supply side of such chains. The non-aggressive attitude of large-scale retailers is crucial constraint to the expansion of organic fruits and vegetables.

Although production in Europe is expanding, there is frequently greater demand than supply, thus substantial opportunities for imports of fruits and vegetables, fresh and processed, particularly for counter-seasonal fresh products and non-temperate zone fruits and vegetables.

The UK market for organic fruits and vegetables is currently a niche market that mainly serves the higher than average income groups. For it to continue to grow at the rates of growth in the past years, price premium for organic fruit and vegetable produce will have to fall.

Producers and exporters of organic fruits and vegetables seeking to sell their products in developed countries which have adopted organic standards and regulations, will have to meet the rules established by the importing country concerned.

In West African countries, most livestock farming is held in small rural farms. Their development by blending new technology with traditional methods can contribute significantly to the generation of personal income for women and so alleviate poverty and promote gender equity. The limitations of financial and material resources facing West African farmers and their organizations dictate more low-cost and cost-effective ways of supporting research and development work in animal agriculture.

In West African countries, livestock production represents an appropriate system to feed the fast growing human population. Poultry production has an important contribution in supplying local populations with additional income and high quality protein. Livestock farmers are valued in religious and socio-cultural circles. However, in poultry animals, high mortality rate does occur among growers, which constitutes to the greatest constraints affecting the development of poultry in the regions of West African countries. The other problems faced by farmers or producers in African countries are breeding methods, feeding, and marketing of the products.

The Food and Agriculture Organization (FAO) of the United Nations has focused on livestock development over the years, the aim of the development is to increase the number of livestock produced in Africa. It has been seen in a different perspective that most livestock production in Africa is undertaken through an extensive system. Looking at West African production practices, nearly every village household keeps domestic fowls (on an average between 5 and 20 birds) and it is estimated that village fowls make up more than 80% of the total fowl population in Africa, estimated at 1,068 million in 1995 (Guèye 1998).

12.1 POULTRY PRODUCTION

Poultry farming provides a high proportion of protein food such as meat and eggs for the world. In poultry farming, farmers must understand that the

individual animal is primarily a unit of production (duck, chicken, goose, pigeon and guinea fowl), designed by selective breeding to have a genetic potential for rapid growth with a high percentage of breast muscles. The production of these group of animals has contributed immensely towards food supply for the world's growing populations over the past years. In addition, poultry provides income and high quality protein for both local and commercial farmers in different parts of the world. In general, *poultry farmers are valued in religious and socio-cultural lives*.

Over the last fifty years, poultry production has undergone considerable expansion throughout the world and has stimulated the continuing increase in the acceptance of meat and egg in human diet. In the UK, poultry production has become increasingly specialized and integrated into a dynamic industry. Simultaneously, there has been an increase in intensive management. Understanding the significance of breed, housing, nutrition, preventive and therapeutic medicine for health, welfare and optimizing production is the basic step for poultry improvements. Adequacy of energy, protein, trace elements—especially iron, zinc and vitamins A, C and E—have long been identified as important elements for the proper immune system functioning (Klasing, 1998). Recently, the importance of balanced fatty acids has been considered to have an effect on poultry immune response, thereby facilitating the diversion of nutrients for its growth and development (Klasing, 1998).

Poultry, in general, has created the concept of “in house” bio-security in areas where diseases are to be prevented by medication, vaccination for viral infections or environmental controls (Vaarst and Hovi, 2004). The bio-security measures help assure that 100% control of veterinary protection is achieved during the management in both small and large scale production. In organic poultry, health standards restrict the use of synthetic substances (prophylactic medicines) and encourages quality production. It is, therefore, encouraged to practice the free range production system which promotes intensive bio-security measures.

Future Plan for Poultry Production

The future state of poultry enterprise will continue to offer many challenges for those responsible for the production. The increase of poultry growth will result in a corresponding reduction in reproductive characteristics (eggs, fertility and hatchability) of parents. The pressures to produce, higher yielding and faster growing birds are a step towards today's marketing systems. However, the recent trend of the poultry industry clearly states that production may swing towards separate sex rearing of birds to better

manage their growth rate, which could compel livestock farmers to pay more attention to the quality produced for world consumption.

Consumers are currently aware of the difference in quality between conventional poultry meat and egg in comparison to the organic production. For effective production and consumers' preference, breeders should concentrate more on the quality instead of quantity.

There are forums focusing on the population growth in the US and in some countries in Europe, a lot of case studies and research have reviewed that continuous growth of population in the world will eventually lead to a problem in food production in future. To avoid this future occurrence, it is imperative to re-amend the situation and concentrate on both crops and livestock production.

Poultry Development

The development of poultry is directed towards its importance in our daily diets. It is currently the cheapest meat in the market due to poultry demand. Researchers and breeders are very keen on conducting research on poultry for the improvement of production of high quality carcasses and eggs. In the advancement, there was a development of new varieties that have the capability of thriving in different climatic and environmental conditions with the intention of meeting the increasing demand of eggs and meat. Meeting the demand of the ever growing population, led to the introduction of pure breed chicken after the revolutionary war. The reason why purebred was introduced was to achieve efficient production and more quality poultry with desirable characters.

Emphasis is now placed on maintaining good records of the performance of poultry as a means of selection and improvement for better analysis of quality, or failure in the system being practised. A well-planned mating system will no doubt improve the efficiency of poultry production in future and will continuously meet the need of the present world population.

The recent application of improved methods in breeding, feeding, management, diseases and pest control and a well designed welfare programme for birds in the later part of the 20th century have played a great role in increasing the efficiency of poultry production.

12.1.1 Practical Poultry Production

The overall goal for breeder managers of poultry is to produce the highest number of top quality chicks per hen house. For hen producers, the main objective is to identify the most economical and efficient methods of producing the maximum number of fertilized eggs. The task will become

more and more difficult as the poultry industry continues to advance towards faster growing systems. Due to the negative correlation between weight gain and reproduction, further increased growth rate is likely to reduce the number of eggs produced per hen housed, and it has become very difficult to achieve their potential genetic for egg production. Nevertheless, female line geneticist can be selected for egg production, but this cannot be done at the expense of growth and yield of the offspring. The physiological makeup of breeders and their eggs may result in the need for altering the hatchable requirements of the eggs produced in many countries (Bramwell, 2005).

The current concepts and practices found in the poultry industry are not to provide a step by step method to successfully raise highly productive birds, but to provide general information used by the industry in the management of breeders to attain high levels of reproduction. Basically, there are two phases to breeder management, *the brooding* and *rearing phase*, *the laying* and *the breeding house phase*. None of these can be neglected without reducing reproduction in the breeding house, the success of brooding and rearing stages determines the quality of birds moved into the breeder house (Bramwell, 2005).

To improve poultry production, the understanding of the relationship between fertility and early embryonic mortality is very necessary. As flocks age, mating frequency decreases, fertility decreases, and embryonic mortality increases. As conditions deteriorate in flocks due to age, additional egg hatching quality problems will occur. Addressing the specific causes of fertility problems as they occur will contribute to improving the number of chicks produced from each breeder flock.

Management of Chicken

Improvement in chicken management has contributed significantly to maximum weight gain with maximum feed intake. Proper daily management of the modern day house is critical to the production of efficient, high quality and profitable broilers. The major areas exist where daily management plays a vital role in chicken production. These areas include proper management of feeding, drinking, and lighting systems, litter conditions, house temperature and ventilation rates. Other areas requiring adequate attention are the sanitation and security, set-up for baby chicks, and harvest preparation. In the recent poultry house, much of what used to be hand labour is now mechanical. Growers can now perform many duties by flipping a switch or turning a knob. Despite the use of the mechanical help, growers must spend a great deal of time in the house in order to be successful. Genetically advanced birds of today, however require greater

attention to ensure ideal house conditions that will allow them to perform up to their genetic potentials (Akinyemi, 2005).

A poultry farmer concentrating on egg production aims to obtain the largest number of high-quality eggs of the correct size from each hen housed in the shortest period of time and at the lowest cost rate. To achieve this, numerous feeding and management programmes must be effected.

Nutrition

Nutrition is an important component in poultry production. A well designed nutritional programme is a requirement to ensure birds reach their growth potential. Nutrition is considered to be one of the most important components in poultry production. Nutrition comprises about 60 to 70% of the total cost used in production. Nutrient formulation greatly affects the growth and performance of poultry animals. Nutritional deficiency leads to poor growth, decreased carcass weight, and poor egg production. Inadequate or imbalanced nutrients can lead to poor health and decrease in the general performance of birds. Feed and feed ingredients also impact water consumption, which can in turn impact litter quality and water balance in the poultry house (Emmert, 2005). Chickens are nibblers, not meal eaters; it is, therefore, necessary for feed to be present in the gastrointestinal tract (GIT) at all times if maximum growth is expected.

When formulating poultry feed, the major nutrient group that must be supplied should include both micro and macronutrients. Birds die without food and water because they are considered to be the most important elements required for their survival.

Nutritional Requirements

The formulation of poultry feed is based on nutrient requirements, recommendation and ingredient nutrient analyses. Poultry diets are designed to be fed in mash form, and must meet all the nutritional needs of different bird species. However, it is not always necessary to provide any supplements like oyster shell or grits and should not be diluted with scratch feed or other grains.

Chicken layer formulation can be applied to other poultry animals. Continuous supply of feed, fresh air, and clean water should be made available to birds at all times to help stimulate the metabolic activities of both growing and already matured birds.

In order to accommodate different mixing capabilities, formulation of different vegetables (such as peanut or corn oil) with and without oil is recommended to be included in poultry ration. The use of lower energy diets

may result in a somewhat longer growing period and reduced feed efficiency. Besides, the absence of energy-giving food in poultry diet will not only affect its growth but also the quality.

In poultry feed, the necessity of adding additives in feeding programmes in conventional farms helps to prevent coccidiosis caused by a protozoan parasite that invades the walls of the intestine. A small portion of corn will no doubt remove the parasite, but will also provide medication.

The use of supplemental vitamins and trace minerals in the micro ingredient mix should be included in feeding plans for poultry. The use of dietary energy and protein is also an essential nutrient for the animals.

Dietary Energy

Poultry needs energy to support its body functions such as growth, maintenance and reproduction. Dietary energy comprises about 40 to 50% of the total feed cost provided for poultry animals (Emmert, 2005). Broilers and other poultry birds eat to replenish their energy needs. When diets contain low amounts of energy, feed intake is increased to meet enough energy needed to be consumed. When the diet contains high amounts of energy, the feed intake decreases to avoid over consumption of energy diets.

Most dietary energy comes from carbohydrates that may either be simple or complex. The complex carbohydrates are usually fibre, rice, maize and milo (grains); they are sources that supply high amounts of carbohydrates to chickens, though small amounts of energy may be supplied to poultry through other sources like oilseed meals such as soybean meal. Energy, however, may come from lipids that may be added directly to the diet in the form of animal fat or vegetable oils, and may also be present in dietary ingredients like corn, soybean meal and animal by-product meals (Emmert, 2005). The digestion and absorption of lipids can be affected by the age of the bird and the degree of assimilation.

The broken down fat in the body of birds produces amino acids which provide energy for them. Protein is an important dietary constituent, which must not be given to birds in excess. The process by which amino acid is used as energy-giving diet in birds metabolically influences the rate of nitrogen (N_2) contained in amino acid. This, however, must be disposed of as uric acid.

Dietary Protein

Proteins are usually made of individual amino acids joined together by peptide bonds, in the form of a chain. Amino acids are classified as indispensable and dispensable amino acids that cannot be synthesised in

the body in sufficient amounts, but must be present in poultry diets. The dispensable amino acids are synthesised in adequate amounts in the body as far as the diet containing enough nitrogen is available to support the synthesis of the nutrients.

The use of amino acids by poultry can be influenced by several factors like age, size, dietary energy level and genetic factors. It is important to note that as the dietary energy level increases, the feed intake decreases. Therefore, it is recommended to make high-energy diets available in order to ensure adequate intake. If diets do not contain all the elements needed to support poultry performance, the diet will be limited in one or more nutrient elements.

The most efficient nutrients in poultry is the limiting one, since it controls the rate of production. Common poultry diet formulations result in a limited amount of sulphur, amino acids (methionine and cysteine) and lysine. As sulphur and amino acids are relatively deficient in soybean meal, therefore, the tendency for lysine to be present in their diets is also not certain.

To avoid restricting growth in poultry animals, supplemental sources of sulphur, amino acids and lysine should be added to their diets when formulating their ration.

The most important aspect of amino acid is the digestibility. Knowledge of digestibility is very important because it indicates how amino acid differs from protein containing ingredients. Understanding digestibility helps to determine how much amino acid should be added to diets.

Amino Acid Requirements in Broilers

Over the past years, there has been a rapid reduction in the marketing age for broilers. This is due to a direct result of genetic selection; improved diets and better management of available resources by producers. A rapidly growing broiler needs to be supplied with sufficient nutrients to meet its requirements to maintain its body weight and growth of all body components, including the feathers. Crude protein and amino acid status of a diet can influence carcass composition of chickens, especially broilers, with increased carcass protein and reduced carcass fat accompanying an increase in essential amino acid content. Increase in the growth rate of broilers has been associated with improved feed conversion efficiency. Though nutritional requirements expressed as proportions of the diet may not change linearly with improvements in performance, a greater understanding of the nutrient requirements for specific factors for optimum immune function requires additional research.

Amino acids like glutamine, arginine, cysteine and taurine, are very important for immune-modulation substrates.

Several research and laboratory studies focussed on the effects of inflammatory responses in growing broiler chickens. The studies results pointed out that inflammation in broilers can lead to diversion in broiler nutrients and also hamper their growth rate and development.

In commercial poultry industries, low-level activation of inflammatory responses can also result in poor performance of birds, therefore, affecting economic performance of the firm. This is because the reduction in poultry growth and performance requires more attention and expects to find a solution to the problem arising in the industry.

However, increased awareness of the mechanisms of regulating immune response in broilers will become more important if production aids like *prophylactic antibiotics* are removed from poultry feeds.

Vitamins

Vitamins play a vital role in the metabolic processes of poultry. The requirement of vitamins by birds is very high. There are two major categories for poultry vitamins (fat-soluble vitamins and water-soluble vitamins). Fat-soluble vitamins need the presence of fat in the diet to be absorbed, this involves vitamins A, D, E and K. Vitamin A is very important for their vision, reproduction and bone development. Vitamin D is necessary for calcium absorption and bone strength. Vitamin E is an antioxidant that stimulates cell protection from oxidative break down. Vitamin K plays a role in blood clotting processes.

Water-soluble vitamins help in the integral cellular metabolism and promotes the synthesis and functions of enzymes. They also help to degrade cellular products. The vitamin B-complex is water-soluble that includes thiamine (B₁), niacin (B₃), pyridoxine (B₆), and cobalamin (B₁₂). Pantothenic acid, folic acid, biotin, vitamin C and chlorine are all water-soluble vitamins.

Poultry reacts rapidly to the deficiency of the above vitamins in their diets. It is, therefore, advisable to give birds adequate amounts of vitamins to promote their growth and maintain body systems for disease resistance.

The absence of vitamins will result in slow growth and formation of poor feathers in the birds.

Minerals

Minerals are of two categories, microminerals and macrominerals. Microminerals are usually required by birds in small amounts. These minerals include zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), selenium (Se), and iodine (I). Microminerals perform a lot of activities in the life of birds when given in the required quantity. These nutrients help in

oxygen transportation, promotion and formation of enzymes, maintenance of healthy cells through antioxidant activities and immunity promotion.

The macrominerals (calcium, phosphorus, magnesium, sodium, potassium, etc.) are usually needed by birds in large quantities. Major or macrominerals like calcium (Ca), are needed mainly for bone and eggshell formation. They also help to transport compounds across cell membranes. Birds require approximately 1 to 5% dietary calcium. This may be found in limestone (calcium carbonate), phosphates or oyster shells. The absence of calcium leads to rickets in birds and affects the formation of quality eggshell.

Calcium requirements in laying hens have been widely studied by various animal scientists and agricultural research centres due to the new genetic make-up of commercial strains, farm management techniques, environmental concerns, and economic considerations. The present research conducted by the US National Research Council (NRC) was to determine the effects of calcium on nutrients requirement in "laying hens". It was noted that hens represent about 17% of US layer industry. The result of the research reviewed that the increased level of calcium from 2.5 to 5.0% in their diets has a significant positive linear effect on egg production and egg specific gravity. The increase in dietary calcium level from 2.5 to 5.0% will increase egg production from 75.3 to 82.4% and egg specific gravity from 1.078 to 1.083 units. However, the calcium level does not have an effect on feed consumption or egg weight in hens, but promotes high quality shell of the eggs.

The production of poor quality eggshell by birds results in substantial economic losses to commercial egg producers as a result of inappropriate nutritional management (Roland, 1988).

Phosphorus (P) is another major macromineral required in relatively large proportions by poultry animals. It is one of the most expensive mineral elements required by the animals. It is, however the third or fourth most expensive nutrient needed in the ration of laying hens; the first being energy providing nutrient, and the second being protein.

The presence of phosphorus in an animal body plays an important role in the body structure and promotes skeletal function, and is also responsible for the key functions in carbohydrate and fat metabolism. Phosphorus is very vital in the transfer, storage and liberation of energy through adenosine triphosphate (ATP). The presence of phosphate ions helps in the maintenance of acid-base equilibrium in poultry systems. Phosphorus plays an important role in promoting all the living cells of both laying hens and non-laying hens.

Over the past six decades, the National Research Council (NRC) in the UK recommended higher levels of calcium and lower levels of phosphorus in laying hen diets. The reason for this recommendation is that a number of reports and research have clearly demonstrated that specific gravity of eggs and eggshell thickness are increased with lower phosphorus levels. In late 1986, the NRC in the UK recommended that a total of 600 mg of phosphorus should be given to laying hens per day. The most satisfactory phosphorus levels for practical feeding will be affected by genetic strains, egg production rate, environmental temperature, ingredient costs and the source of supplemental phosphorus.

Environmental temperature, one-way or the other has a significant influence on phosphorus requirement in laying hens. Several research studies have demonstrated that low dietary phosphorus reduces survival of both young chickens and laying hens when exposed to heat and stress. Any poultry receiving low phosphorous diets or lacking this element for 24 hours has the tendency of being susceptible to heat stress. From scientific observations, it has been reviewed that high mortality is usually common among broilers as a result of low rock phosphate in their diet.

Sodium (Na) is the third major mineral that must be present in poultry diets. Dietary deficiencies of sodium are very rare. Excess sodium has been a cause of great concern by several researchers. High sodium level causes increase in water uptake by birds and may lead to flushing syndrome (wet excrete) and wet litter. Other macrominerals required by birds include potassium (K), chlorine (Cl), and magnesium (Mg).

Table 12 Body weights and feed requirements of broilers

<i>Age (weeks)</i>	<i>Cumulative feed consumption (g)</i>		<i>Weekly energy consumption (ME kcal/bird)</i>		<i>Cumulative energy consumption (ME kcal/bird)</i>	
	<i>M</i>	<i>F</i>	<i>M</i>	<i>F</i>	<i>M</i>	<i>F</i>
1	120	110	385	350	385	350
2	380	350	830	770	1,215	1,120
3	770	705	1,250	1,135	2,465	2,255
4	1,305	1,205	1,710	1,600	4,175	3,855
5	2,045	1,850	2,370	2,065	6,545	5,920
6	3,025	2,650	3,135	2,560	9,680	8,480
7	4,120	3,560	3,505	2,910	13,185	11,390
8	5,330	4,530	3,870	3,105	17,055	14,495
9	6,650	5,540	4,225	3,230	21,280	17,725

Source: Firman (1993)

Notes: ME—Metabolizable energy

kcal—Potassium calories

Table 13 Nutrient requirements of leghorn-type chickens as percentages or units per kilogram of diet

<i>Energy base</i>	<i>Growing 0–6 weeks</i>	<i>Growing 6–14 weeks</i>	<i>Growing 14–20 weeks</i>
kcal ME/kg diet *	2,900	2,900	2,900
Protein (%)	18	15	12
Arginine (%)	1.00	0.83	0.67
Glycine and serine (%)	0.70	0.58	0.47
Histidine (%)	0.26	0.22	0.17
Isoleucine (%)	0.60	0.50	0.40
Leucine (%)	1.00	0.83	0.67
Lysine (%)	0.85	0.60	0.45
Methionine + cystine (%)	0.60	0.50	0.40
Methionine (%)	0.30	0.25	0.20
Phenylalanine + tyrosine (%)	1.00	0.83	0.67
Phenylalanine (%)	0.54	0.45	0.36
Threonine (%)	0.68	0.57	0.37
Tryptophan (%)	0.17	0.14	0.11
Valine (%)	0.62	0.52	0.41
Linoleic acid (%)	1.00	1.00	1.00

Source: Firman (1993)

Table 14 Nutrient requirement for leghorn

<i>Age (weeks)</i>	<i>Body weight/g*</i>	<i>Feed consumption (g/week) **</i>	<i>Typical egg production (hen-day %)</i>
0	35	45	-
2	135	90	-
4	270	180	-
6	450	260	-
8	620	325	-
10	790	385	-
12	950	430	-
14	1,060	460	-
16	1,160	460	-
18	1,260	460	-
20	1,360	460	-
22	1,425	460	-
24	1,500	595	10
26	1,575	665	64
30	1,725	770	88
40	1,815	770	80
50	1,870	765	74
60	1,900	755	68
70	1,900	740	62

Source: Firman (1993)

Table 12 shows body weights and feed requirements of leghorn-type pullets and hens. Pullets and hens of leghorn-type strains are fed with the feed name in Table but are occasionally controlled to limit the body weights. The values shown as indicated by Firman (1993) are typical, but may vary with strain differences, season and lighting. Consumption of diets containing 2,900 ME kcal/kg varies in birds, according to the caloric density of the diet, environmental temperature and the rate of production.

Table 15 Nutrient requirements of broilers as percentages or as units per kilogram of diet

<i>Energy base (kcal)</i>	<i>Weeks 0-3</i>	<i>Weeks 3-6</i>	<i>Weeks 6-8</i>
ME/kg diet *	3,200	3,200	3,200
Protein (%)	23.0	20.0	18.0
Arginine (%)	1.44	1.20	1.00
Glycine + Serine (%)	1.50	1.00	0.70
Histidine (%)	0.35	0.30	0.26
Isoleucine (%)	0.80	0.70	0.60
Leucine (%)	1.35	1.18	1.00
Lysine (%)	1.20	1.00	0.85
Methionine + Cystine (%)	0.93	0.72	0.60
Methionine (%)	0.50	0.38	0.32
Phenylalanine + Tyrosine (%)	1.34	1.17	1.00
Phenylalanine (%)	0.72	0.63	0.54
Threonine (%)	0.80	0.74	0.68
Linoleic acid (%)	1.00	1.00	1.00
Tryptophan (%)	0.23	0.18	0.17
Calcium (%)	1.00	0.90	0.80
Phosphorus, available (%)	0.45	0.40	0.35
Potassium (%)	0.40	0.35	0.30
Sodium (%)	0.15	0.15	0.15
Chlorine (%)	0.15	0.15	0.15
Magnesium (mg)	600	600	600
Manganese (mg)	60.0	60.0	60.0
Zinc (mg)	40.0	40.0	40.0
Iron (mg)	80.0	80.0	80.0
Copper (mg)	8.0	8.0	8.0
Iodine (mg)	0.35	0.35	0.35
Selenium (mg)	0.15	0.15	0.15
Vitamin A (IU)	1,500	1,500	1,500

Contd.

Table 15 Contd.

Vitamin D (ICU)	200	200	200
Vitamin E (IU)	10	10	10
Vitamin K (mg)	0.50	0.50	0.50
Pantothenic acid (mg)	10.0	10.0	10.0
Niacin (mg)	27.0	27.0	27.0
Vitamin B12 (mg)	0.009	0.009	0.003
Choline (mg)	1,300	850	500
Biotin (mg)	0.15	0.15	0.10
Folacin (mg)	0.55	0.55	0.25
Thiamine (mg)	1.80	1.80	1.80
Pyridoxine (mg)	3.0	3.0	2.5

Source: Firman (1993)

Table 16 Recommended daily nutrients for laying hens

Crude protein	17 g
Metabolizable energy	280 kcal
Methionine + Cystine	360 mg
Lysine	720 mg
Calcium	3.5 g
Available Phosphorus	0.4 g
Sodium	0.18 g

Source: Leeson (2001)

Table 17 Nutrient formulation for young chicks

<i>Feed formulas for small poultry flocks</i>	<i>Pullet starter (chicken)</i>	<i>Pullet grower (chicken)</i>
Age in Weeks	0-6	7-12
Ingredients	Percentage	Percentage
Yellow corn	71.61	77.10
Soybean meal (48.5%)	24.55	19.48
Ground limestone	1.24	1.26
Dicalcium PO ₄ (18% P-22% Ca)	1.77	1.33
Microingredients	0.50	0.50
Salt	0.33	0.33

Source: Lesson (2001)

Feeding for Health and Welfare

To secure the best results in growth, egg production, hatchability, fattening, and good health, chicks should be fed with balanced diets (balanced rations). It is expected that chicks be fed according to age and the purpose of

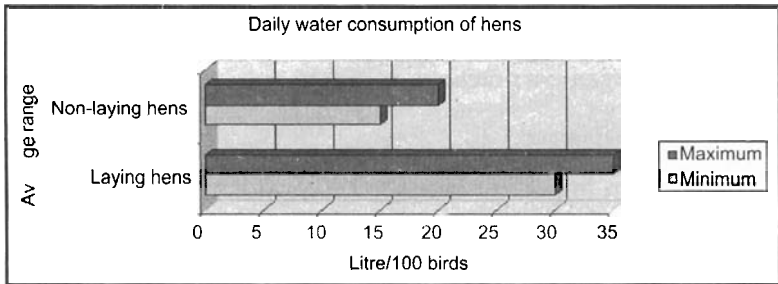
production. Growing chicks, for example, should be given more protein in their diets than the laying hens. Fattening birds—table birds and cockerel—should be given less protein but more carbohydrates. Hovi et al. (2001b) explained that there are some factors affecting feed intake in poultry. The assumption was that lack of proper understanding of the ration formulation in bird management can lead to potential deficiencies in home-like, home-grown and home-mixed ratios, which are more likely to be of low nutrient density that may result in thin intestinal contents and poor absorption of nutrients in the short digestive tract of poultry. To achieve the best production, it was strongly advised that acceptability of coccidial water-administered vaccines in organic poultry hatcheries should be clarified. They further suggested that poultry should be allowed to practice choice feeding where they can choose their own rations. For better development of birds, a high level of limited amino acids in poultry diets is needed. More importantly, the adjustability of production levels to available diet is imperative rather than changing feeding standards.

12.1.2 Role of Water in Chicken Development

Water is involved in every aspect of poultry metabolism. It plays an important role in regulating the body temperature, helps in the digestion of food, and contributes to the elimination of their metabolic waste products. *At normal temperatures, chickens consume less water than feed.* When heat stress occurs, the water consumption increases to almost double the amount taken during cold season. A safe and adequate supply of water is, therefore, an essential element for efficient chicken production.

In poultry industries, the use of water with adequate physical, chemical and microbiological quality is fundamentally important in birds management and production. Water should be made available to birds always and any water given to them should be free from obnoxious substances that may affect their growth and quality. Farmers and producers should be aware that drinking water plays an important role in the transmission of some bacteria, viral and protozoan diseases that are among the most common poultry diseases (Amaral, 2004).

However, the ability for hens to consume water is subject to considerable variation. This depends on the type, age and condition of the hens, available feed, climatic and environmental conditions, and the quality of the water available. The daily average water consumption is mainly used for fixing long-term storage needs. To improve the quality of birds, feed and water should be kept in strategic locations in their houses. Water intake can be a limiting factor in birds' growth. If birds cannot drink, they will not eat. Water availability and delivery should be planned for weather extremes.



Source: Akinyemi, (2005)

Graph 1 Relationship between water consumption of laying and non-laying hens.

12.1.3 Incubation

When hens lay fertilized eggs, the eggs are ready for incubation either by the hens or by artificial means. However, the present poultry farming system requires natural means (organic farming), which may affect the incubation of many eggs, as a large number of hens are needed to incubate the eggs. In natural incubation, hens sit on their eggs for a period of 21 days after the eggs have been completely laid. At this stage, the hen provides an optimum temperature required for hatching. This method of incubation does not favour commercial chicken production due to the limited number of chickens produced.

The synchronized natural incubation is specifically a management used to control the timing of the natural incubation by five or more broody hens. The technique is practised in order to increase the production of eggs in free-range traditional hens. It ensures that the accepted number of eggs are hatched by hens. From investigations, it has been observed that synchronized incubation has tremendously improved the production of eggs for traditional producers. Besides, the synchronized natural incubation is achieved by collecting the eggs from the nest daily. During the collection of eggs from the nest, it is advisable to leave *plastic toy eggs* in the nest to encourage continuous laying of eggs. The absence of eggs in the nest discourages hens from laying in a particular nest. However, producers should not leave eggs for more than a week, as eggs can only remain viable at room temperature just for a week.

The synchronized technique can permit traditional farmers to manage a few hens, which can hatch about 50 to 60 chicks at a time. As the chicks are hatched simultaneously, this technique helps farmers to make the most efficient use of heaters for artificial brooders and other facilities, as well as

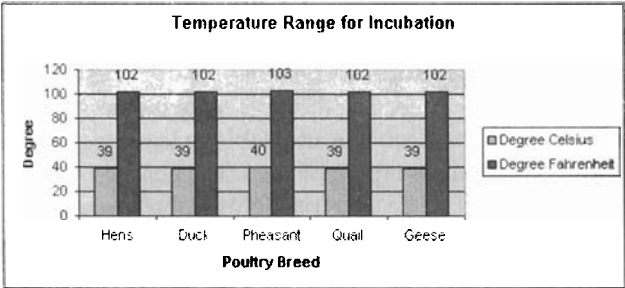
labour, vaccines and other inputs required for chicken management. The practice helps improving the brooding system in the overall production efficiency in management practices.

Artificial Incubation

Temperature is an important factor to be considered during incubation. Variations of more than one degree from the optimum will adversely affect the number of eggs that will successfully hatch. In home-type incubators, the temperature varies considerably between the top and the bottom of the eggs. With these types of incubators, a temperature at the top of the eggs of 38°C (101°F) for the first week, 39.5°C (102°F) for the second week, and 40°F (103°F) till hatching gives the best results with eggs of most species. In modern commercial poultry management, forced-draft incubators of temperature ranging between 39.7 °C (99–100°F) are maintained throughout the incubation period. Most operators find that in large machines, some provision must also be made for cooling to maintain this constant temperature. Embryonic development produces considerable heat. If this heat is not dissipated, injury to the embryos may occur.

In an artificial incubation, farmers should ensure that the electric bulb is adjusted to provide the maximum temperature required for the incubation. The required temperature for incubation in a poultry house should not exceed 39°C especially for hens, ducks, quails and geese.

The developing embryos are fairly tolerant to short term temperature drops and anyone using artificial temperature for incubation need not be much concerned when the temperature is dropped but to keep inspecting the eggs. The graph 2 below shows the incubation temperature range for the named poultry animals on hatching rates in poultry houses.



Source: Akinyemi, (2005)

Graph 2 Temperature rate for incubation

12.1.4 Relative Humidity Control

Controlling relative humidity gives producers an upper hand to control litter moisture and ammonia. In a poultry house, birds continuously add moisture to litter. If the relative humidity of the atmosphere is too high, moisture added to litter by birds would evaporate from the litter, resulting in the formation of a cake. As soon as cake is formed, ammonia which is present in the litter is likely to become pungent and gaseous. If producers can control relative humidity and ventilation to below 70%, there is a high possibility that the moisture will evaporate from the litter to limit cake formation and maximizing ammonia. However, if relative humidity becomes very low to below 50%, the producer may need to reduce the timer fan settings to ensure that too much moisture is not removed from the litter.

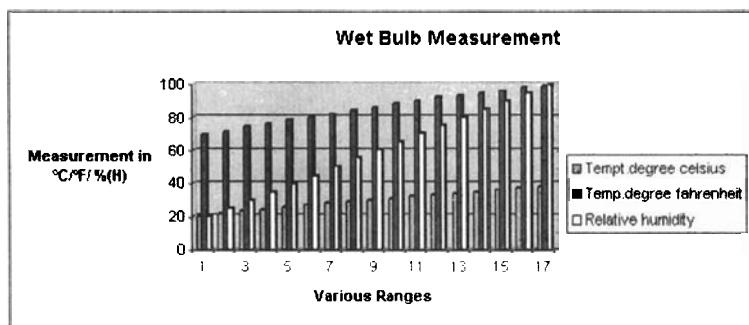
Producers should not decrease timer settings on rainy days. It is, however, imperative to note that each time a producer increases the temperature of air by 5°C, the moisture holding capacity of the air doubles. Any attempt to bring in fresh air from outside through adjustable air inlets to mix with the already warm air inside poultry house, will dry out because the warm air has already accumulated inside. This occurs as a result of increased moisture holding capacity as the temperature rises. For example, if the air outside is 17°C and 100% humidity, and if the producer brings in the 17°C air through the inlets and heats it up by 5°C to 22°C, moisture holding capacity of the incoming air doubles and reduces the relative humidity of the incoming air by 50%.

Growers must have in mind that keeping relative humidity in check does not mean ammonia may not be formed. As long as manure, water and heat are in the poultry house, there will be ammonia. Whether producers have a checking routine of relative humidity, the timer fan settings must be increased to keep ammonia within acceptable levels. Therefore, reducing the amount of moisture through good ventilation will significantly minimize the formation of ammonia.

12.1.5 Air Movement

The control of air movement within a poultry house permits the producer to increase or decrease birds' cooling. In hot weather, tunnel ventilation is necessary to produce maximum airflow over the birds. With older birds, air speed between 121 and 151 m/min moving over the surface of birds to produce approximately 2.5°C wind chill will affect and trap heat from between birds.

Producers need just 60 to 90 m/min of air speed to accomplish appropriate production for younger birds. In cold weather, ceiling inlets



Source: Akinyemi (2005)

Graph 3 Temperatures and relative humidity measurement required for a laying hen.

may be used to direct incoming cold fresh air and remove stale air from the birds. The incoming cold fresh air thus mixes with warm, moist air that has already accumulated at the ceiling, thereby maximizing the birds' chilling.

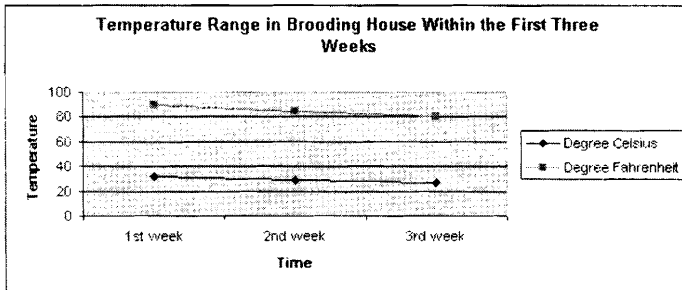
12.1.6 Brooding Hen

A typical broiler house under large-scale production of the modern production method should be about 43' by 500' with two 10-2 ton feed storage bins located beside each house. In cooler weather, poultry house *heat should be turned on 24 to 36 hours before the arrival of chicks to allow adequate time for the litter to warm.* With today's advanced heating system, air temperature can be brought up to brooding temperature quite rapidly, but it takes much longer to warm the litter. Baby chicks have very poor heat sensory systems within the first few days of life and lose a lot of heat through their feet, especially if the litter is cold, or the temperature is not adequate. If the chicks are kept at a low temperature, they may become stunted and poorly developed.

In general, young chicks are much easier to raise. With just little equipment and a small piece of land, raising chicks can be quite successful and profitable. At the early stages of a bird's life, the most important need is heat because of the high rate of mortality that may occur at these stages of development. When poultry of any species is raised, steps required for standard management should be adhered to.

Eggs are hatched after a period of two to four weeks of incubation (precisely 21 days). Hens can be provided with stimulus by the young chicks to change their work from egg incubating to brooding. In the absence of very few brooding hens, artificial brooding may be necessary since chicks can

perform very well under artificial brooding when the heat regulation system is done by a person who has the technical know-how in the operation. However, poultry breeders should bear in mind that brooders should be lowered to 20 to 30 inches above the litter to help warm the floor before chick arrival.



Source: Akinyemi (2005)

Graph 4 Brooding temperature in degree Celsius and in Fahrenheit

Steps for Appropriate Brooding

1. An appropriate well-bedded, well-ventilated, draft-free, predator-proof, environment with abundant natural daylight where the chicks can comfortably adjust to:
 - ❖ A warm temperature of 90-95° F at night to enable them to sleep
 - ❖ A cool temperature of 65-75° F to help them move around
2. A breeder should allocate at least 30 minutes for the observation of the chicks on arrival for the normal pattern of activities like:
 - ❖ Provision of heat during brooding
 - ❖ Provision of clean drinking water
 - ❖ Provision of quality feed with a minimum of two to three grits in their diets
 - ❖ Provision of nest under heat with less population
3. Chicks should be observed at least 10 to 15 minutes each day and ensure the adjustments of:
 - ❖ Drinking trough
 - ❖ Ventilation channels

12.1.7 Temperature Control in a Poultry House

Temperature control in a poultry house is very necessary. The main reason for controlling temperature in poultry management is to ensure that

maximum temperature is achieved. Producers should be aware of temperature control in the management systems.

Control of temperature is a critical factor that determines poultry production. Chicks can regulate their own body temperature if enough area is provided for them to move around. If the room temperature is very high, birds feel very uncomfortable. In a poultry house, there should be an optimum temperature of about 30 to 35°C to encourage better performance and lay.

12.1.8 Culling Laying Hens

Culling is done to remove deformed birds, wobbly, or weak chicks as soon as they are hatched. Scrawny and unpromising individuals should be slaughtered and eaten or sold, while the fittest chicks should be allowed to survive. If there is a diseased bird among others, the disease may spread easily if it is not removed from the cage or poultry house. To achieve profit in poultry enterprise, farmers should practice culling to avoid the problems that may reduce economic value in future.

It has been cited in a lot of literature reviews that the demand for information on culling pullets is rapidly increasing, and producers, farmers, and researchers should be given the chance to introduce the best possible means for improving the methods of culling, with the objective of achieving the best management.

The culling of domestic poultry other than chickens has not been given serious attention, but it seems that there has not been any logical reason why poultry animals (ducks, geese, turkeys and guineas) are neglected. The neglect of birds will have an adverse effect on market demand. Nevertheless, when there is scientific concentration on birds, farmers can develop more interest in production and stimulating consumers' interest to purchase more, as diseased birds and infertile ones are separated from the healthy birds.

12.2 MANAGEMENT SYSTEM

Organic farmers keep hens in free-range systems. A free-range system is enriched for hens and usually brings several advantages for farmers. Behavioural elements usually occur in laying hens but they are possible in poultry houses, sunbathing attitude can be shown in sunlight but it does not occur in artificial light (Huber, 1987). Fowls spend two-thirds of their time searching for food in their natural environment. The absence of food in poultry management will lead to deficiency diseases and poor productivity. Free-range systems have a great influence on animal health, welfare and

product quality. Lopez et al. (1998) suggested that some constituents of grass might be essential for the production of eggs rich in (*n*-3) fatty acids. For better growth of fowls and high production, outdoor areas with trees and installations providing shade and protection for fowls, and the leaf residue of trees which provides forages for birds, would be beneficial.

To improve distribution in a management system, *the basic factor to consider is the necessity to change other factors rather than concentrating on group sizes. Flock size is another important criterion to consider when a hen run should be used during management*, but the need to keep laying hens in moderate flock sizes for better management practices is also imperative. The results from many *scientists demonstrated that the quality and variation of structures influence the use of hen runs more than the amount of structures* (Lopez et al., 1998). It was pointed out in the demonstration that structural influence may probably be a result of the individual differences in hens as some of them may be attracted by some structures whereas others may not. In addition, the needs and characteristics may keep changing in the different phases of a birds' life.

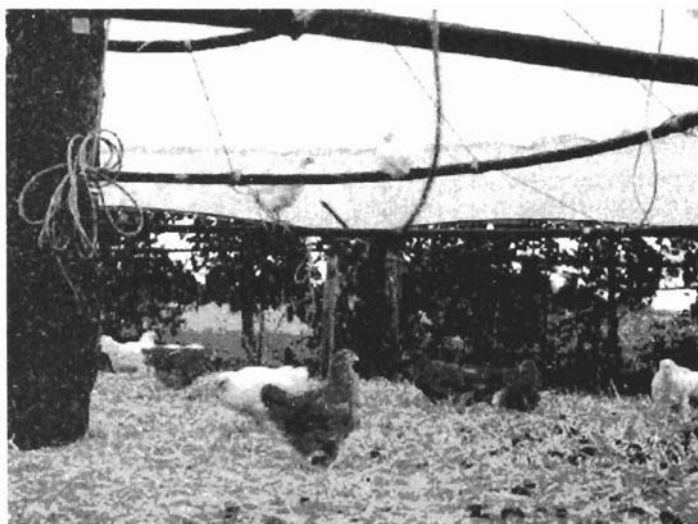
12.2.1 Pastured Poultry (Extensive System)

Pastured poultry production is a poultry production system involving grassroot movements that focus mainly on farm-scale production and direct marketing. It has been developed from scratch by hundreds of family farms, and is driven by consumers seeking an alternative to conventional poultry (Fanatico, 2002). The aim of this type of enterprise is to provide supplementary income for rural and small-scale producers.

In a pasture or free-range production system, farmers or producers usually purchase a day old chick via an order from independent farmers. The chicks purchased are usually sound, free from diseases and of good quality. The essence of this is to maintain quality chicks.

A pastured poultry farmer, Mr. Weiland Max, was interviewed on the 26th January 2005 in Freudenthal, Hesse State in Germany. The interview was focused on his poultry management system. During the interview, (Weiland) pointed out that pastured management system permits the movement of poultry houses from one place to another. In his case, the poultry houses are normally rotated every 14 days. The reason is to enable the fowls to have access to fresh forage. He also mentioned that the movement helps to destabilise the onset of pests and diseases that may have started to build up in the existing environment. He mentioned that the rotation provides clean and conducive atmosphere for birds. Better atmosphere and access to a fresh pasture of forage promotes the welfare of birds and improves productivity.

Weiland has 730 chickens (15 males and 715 females) in his poultry house, mainly of high breed. He claims that most of the birds are bought from "Bavaria" in Germany that he has never experienced any difficulty in keeping the birds under such a system. He indicated that chickens should not be subjected to depression, as depression can result in poor production. To achieve the best product in any management system, the expression of their natural behaviour and good welfare programmes should be designed by the producers. The absence of good management practice will no doubt lead to poor performance of chickens.



Source: Hermansen and Horsted (2004)

Fig. 15 Poultry house with sitting places

Weiland advised that "provision of a sitting place in the poultry house to allow an efficient feeding of the fowls is very necessary", in addition, the provision of light, during both day and night, should not be neglected. The provision of light, especially at night, controls the killing of young chicks caused by rodents. Farmers should ensure that balanced ratios are provided for chickens to avoid feather pecking and cannibalistic practices.

Chickens should be provided with enough space to express their natural behaviour like perching, dustbathing, etc. In Weiland's farm, each chick is entitled to a space of 15 m² and this spacing has encouraged better performance of the birds. Spacing prevents the act of cannibalism. More importantly, ventilation in the poultry house helps prevent cake formation of the litter as there is good circulation of air.

12.2.2 Range Production

In a free-range system, birds have greater freedom to express their natural behaviour. However, in most cases they face a greater risk of contracting disease carried by wild birds and other microorganisms within their environment. In free-range poultry production, it is extremely necessary to care for the birds by providing all the necessary attention required for better production. Some of the care required by the birds includes fresh air, clean feed and water, well protected from predators, provision of shelter against cold, rain, wind and sun.

This production requires a lot of land and is usually part of a diversified operation with ruminants. Mixed husbandry could be necessary in range poultry production. Purchasing land for the purpose of extensive poultry management is seen to be more profitable in the management system. Increased farm diversity can enhance biological diversity and environmental quality. Soil fertility is also seen as a major motivation for free-range poultry production. Many producers have taken the advantage of free-range poultry manure to improve their pastures for ruminants. Free-range poultry is essential in reviving a played-out farm on a shoestring budget. A lot of fertility in poultry manure is obtained from concentrate feed which is an important input in poultry production. It is believed that layer manure contains about 1.5% nitrogen (N), 1.3% phosphorus (P), and 0.5% potassium (K). Broiler manure is usually mixed with litter. Birds deposit a lot of manure in their houses at night. These "night droppings" are collected and spread directly on pastures, or may be composted before being applied on the field.

Litter is considered a problem in the conventional poultry industry. Too much application of litter to the ground on a conventional system leads to nutrient pollution.



Source: Fanatico (2002)

Fig. 16 Free Range System

Poultry needs to be encouraged to forage in an open land (Fanatico, 2002). As shown in the photograph above, the entry to the poultry house should have a slight incline and the building should have many exits, for easy movement of the birds. Peepholes are required in good poultry houses to encourage their activities. Scottish studies had once examined foraging habits of chickens when yarding; it was observed that birds stuck close to their houses and made use of very little area of the total land available. Encouraging birds to forage reduces stocking density around their pens. As a result of poultry being involved in a jungle environment, they may not be attracted to open pastures. They are provided with well-secured settings like bushes, walls, straw bales, constructed shelters, and trees. To encourage foraging, producers should sometimes move their feed and water containers away from them so that they move out. Production systems other than yarding are more conducive for birds to forage. Some birds may be more prone to foraging compared to others, for example, the Cornish cross is a typical forager. It is, therefore, advised that consumers make forage available during brooding in order for birds to forage at the appropriate time.

12.2.3 Semi-intensive System

A larger-scale range poultry production system is the semi-intensive system, which is widely used in the world but not very popular in the US. David Wilson once tried this system on a commercial scale in the US but poultry farmers did not encourage the semi-intensive method. In this system, a permanent house is usually needed and birds are occasionally allowed access to range. The range can be rotated by allowing access through different doors (popholes). It is necessary to rotate the yards where the birds are kept, otherwise the place where the birds are kept will become very dirty.

Farmers with redundant buildings may use this system in poultry production. These production systems are based on one species and mostly domestic chickens (*Gallus domesticus*) are kept. The flock sizes in intensive production systems are normally in thousands, whereas in the semi-intensive or backyard production system, flocks range from 50 to 200 birds per hectare.

The yards where birds are reared should be covered with straw, as this facilitates the conversion of faeces and straw into manure. Recommended land area for their houses should be 0.5 m², to permit the birds to move within the covered area. Birds kept under a semi-intensive system usually have access to fresh green material, which provide vitamins and minerals for them. In the smallholder poultry production system, scavenging is the main feeding system. Unfortunately, until now there has not been a reliable method of estimating the scavenging feed resource quantitatively or

qualitatively to enable estimation of input-output relationships in the feeding system. Guaranteed (1992) and Tadelles (1996) attributed much of the low performance of the birds to the poor feed resource base. Promoting the use of unconventional feed resources like termites, maggots and worms will help increase the scavenging feed resource base.

The advantage of this system is that there is low capital cost involved in the management. Traditional farmers may provide more care for hens as they are sometimes given food and water, compared with the free-range system. Disease outbreak may be controlled. However, the disadvantages are that draught and cold winds may adversely affect the number of eggs produced and there may be intestinal worms, which may build up in the houses.

12.2.4 Intensive System

Intensive management involves keeping birds in permanent buildings. The major advantage is that less land is required and there is a considerable reduction in labour cost. The disadvantages are the high cost of housing, and easy spreading of diseases which may occur when appropriate measures are not taken. However, the intensive methods are of two types—**Battery Cage** and the **Deep Litter System**. Most conventional farmers practise this system. The battery cage is the most popular system and the chickens are confined to a cage that permits limited movement. The cage, which previously housed one hen, is now used to house two due to the production of small-bodied birds such as the *White Leghorn* and *Skye's hybrids*. The original concept of deep litter was imported from America in 1949. The birds were housed in a controlled environment with the freedom to move about, but with no access to the outside (Twince, 1985).

In the intensive system, farmers are able to keep accurate records of each bird, thus facilitating the culling of unproductive birds, hence the remaining birds are able to feed and take up water comfortably. Moreover, the feeding trough cannot easily be contaminated, which helps to minimize the spread of diseases. Egg production is very high as all the eggs are collected in trays. Out of doors, parasites such as coccidia can build up in the ground and cause unthriftiness and sickness in birds.

In cages, hens find it difficult to move around and are denied the primitive satisfaction of stretching their limbs. There is *good evidence that the system leads to bird frustration and frustration increases with time*. As a result of this, cage production system is not encouraged for poultry production due to high disadvantages it has on chickens. Nevertheless, there has been an ongoing debate on cage system of production. It does not encourage normal behaviour as the area allocated for birds is limited (Akinyemi, 2005).

In a battery hen house, the temperature is maintained at 21°C. The hens are confined in a wire cage with a wire floor at a stocking density of 450 cm² per bird, which causes *damage to their feet and osteoporosis (weakening of bones)*, largely through inactivity and predisposing them to fractures. On the other hand, caged birds are remarkably free from infectious diseases, partly because their droppings fall through the floors of the cage and are carried away.

Deep Litter System

In deep litter system, birds are kept in a well-ventilated house, with a concrete floor that is built to about 10 cm with a litter of bed absorbent material like straw, wood shavings, sawdust, or dry grass. The litter is stirred up with a fork at frequent intervals to encourage the multiplication of microorganisms within it. The break down of hens' droppings would eventually be converted into litter and friable material that is normally odourless and comparatively hygienic.

A deep litter house normally consists of a concrete floor, with sidewalls of about one metre high, and a roof, usually of corrugated iron or asbestos sheets, supported about 2-2.5 metres from the floor by wooden or metal poles. The space between the roof and the walls are covered with wire gauze to ward off predators while permitting free movement of air and entry of light.

Birds are supplied with water, feed, laying nests and perches. The ratios supplied are well balanced. This method provides efficient management but it is never the best method since birds are restricted from moving around large areas to get adequate exercise. It is never labour intensive and there is reduction or loss of eggs and birds by vermin and thieves. It requires less capital than the battery cage system. The cost of housing is quite exorbitant. Another disadvantage of this method is that the *birds develop traits such as pecking, egg eating, feather plucking and cannibalism*.

Battery Cage System

The battery cage system for laying hens was introduced commercially on a wide scale in the 1950s. It has become the predominant method for maintaining hens. Cages provide egg producers with an efficient and cost-effective means of collecting eggs, disposing of waste, reducing feed wastage, maintaining adequate environmental temperature, and inspecting the condition of individual birds at regular intervals.

Cages have come under increasing criticism, however, largely because of the behavioural restrictions that are imposed upon the birds. Cages do not

provide an environment that allows the expression of behaviours like nesting, perching, and dust bathing. Space allowances for laying hens have also been criticized, although how space allowances should be determined is an extremely controversial topic. In recommending guidelines for husbandry, *Practices for Laying Chickens*, the United Egg Producers in the US suggested 48 square inches per bird as a minimum space requirement for caged hens; however, the European Community has mandated a minimum allowance of 75 square inches per bird. Both the European Community and the United Egg Producers guidelines can, therefore, be interpreted as providing a minimum space allowance of 12 square inches per M² of liveweight, although it is more common to express space allowances per bird.

In general, cages provide the best means for ensuring bird health, egg quality and safety.

12.2.5 Effects of Environment on Production

Environmental impact depends on whether poultries are kept in good condition or are fed indoors or outdoors, or have access to sufficient feed within the boundaries of the farm (ranching and grassland).

Climatic factors can have a major effect on the rate of transmission of many infectious diseases to poultry animals. Microbial agents and their vector organisms are sensitive to factors such as temperature, humidity, precipitation, surface water, wind and changes in vegetation. This applies particularly to vector-borne diseases (VBDs), such as Rift Valley Fever (RVF) transmitted by mosquitoes; and bluetongue (BT)—both transmitted by biting midges (*Culicoides* spp). Climatic change does alter weather patterns, which in turn affects intensity, and seasonality of many vector-borne and other infectious diseases of both poultry and ruminants. However, weather condition is one of the key factors that determines animal farming systems.

Considerable progress has been made in dissecting and defining the climatic and environmental factors that influence vector biology. Data has generally been obtained by a combination of field and laboratory studies from different authors. The approaches, combined with satellite remote sensing, geographical information systems (GIS) and biomathematical modelling have been used to develop simulation models to predict when and where disease outbreaks are likely to occur and how things might alter with climate change. Armed with this information, control strategies like the use of prophylactic vaccination and vector control, are now used to protect animals in advance, prior to the spread of a disease, thereby reducing its impact.

For example, successful attempts have been made to model the abundance and distribution of *Culicoides imicola* in the world, the vector midge of African Horse Sickness (AHS) and Bluetongue (BT) viruses. The abundance of *C. imicola*, together with associated climate data have been analyzed in combination with certain satellite-derived variables with the aim of developing models of *C. imicola* abundance to predict the risk of AHS and BT.

Some VBDs are zoonotic diseases that cause serious illness and death in humans. Climatic change is likely to increase the prevalence and incidence of many such diseases (geographically or from season to year-round). For example, global warming resulting in the rise of sea level could displace some human populations, perhaps resulting in migration into wilderness areas where zoonotic infectious agents are being transmitted in silent life cycles.

It is predicted that global warming will be characterized by more frequent storms and flooding in certain areas. It is well-known in Great Britain and other parts of the world that higher temperature results in increased humidity and more extensive surface water might result in increased insect populations and a higher incidence of VBD. On the other hand, periods of drought will cause the extensive migration of pastoral herds in search of water and grazing and favour the spread of disease by vectors and by contact between animals.

Heavy rainfall followed by drought is a critical combination causing high disease epidemics in both temperate and tropical regions. High temperatures during drought increase vector population growth rates within an environment.

Environmental Change and Variability

There are a number of problems associated with environmental assessment and monitoring, all related to environmental change. Very often the information on which the assessment is based is for a limited time frame. There is need to distinguish between 'actual' environmental change and 'normal' environmental variability within the environment where animals are raised; in many cases the impact of environmental damage does not show itself until well after the damaging activities have taken place, and there is a need to look at the cumulative impacts of many minor activities that individually are not significant, but together may form a major threat. Environmental changes have significantly affected animal welfare and productivity in the world for several years now. To avoid the continuous increase of this problem, the understanding of environmental changes and

variability will go a long way in preventing the future occurrence of some zoonotic diseases causing severe reduction in poultry production.

Change and Variability

All systems exhibit environmental variability—weather patterns result in seasonal and annual variations. The concern is for environmental change—where factors such as climate change or human activities result in irreversible changes to the environment. Unless a long-term perspective is taken, long-term variability can be mistaken for irreversible change and development interventions can seek to address non-existent problems. There is need to assess any changes that can be seen to have occurred within a longer time frame related to the variability of the system. This will help monitor the environment and bring out the best methods of controlling future occurrence of poultry diseases.

12.2.6 Heat Stress in Broilers

Broilers subjected to high environmental temperatures exhibit many behavioural changes which allow them to re-establish heat balance within their surroundings. Broilers rest more during the periods of heat stress. Some birds will stand quietly while others simply crouch near walls or waterers. Usually, their wings are spread away from the body to promote cooling by reducing body insulation. Within the bird, blood flow is diverted from certain internal body organs such as the liver, kidneys and intestines to dilated blood vessels of the peripheral tissue (skin) in order to facilitate heat loss (Gary and Butcher, 2003).

Heat loss through evaporative cooling allows the broiler to dissipate the heat it generates. Nevertheless, panting requires increased muscle activity and this results in increased energy requirement that is associated with heat stress. Therefore, decreased energy efficiency also accompanies hot weather. Panting would normally be expected to occur when the ambient temperature is near or above 30°C. Relative humidity influences evaporative heat loss through panting. Broilers, as well as other domestic poultry, cannot tolerate high temperature coupled with high relative humidity. Death due to heat exhaustion will occur very quickly, especially in heavier birds, if both temperature and humidity are high. In normal birds, panting removes approximately **540 calories per gram of water lost by the lungs** (Gary and Butcher, 2003). Broilers kept in an extremely hot environment reduce their feed consumption. Reduction in feed intake, however, results in decrease of daily diet, which is responsible for growth. Research data clearly shows that

the survival rate of broiler decreases as feed intake increases during heat stress, especially during the hottest part of the day.

Alleviation of Heat Stress in Broilers

In hot environment, open-style houses with adequate ventilation for air movement and water consumption are essential. Ventilation should be maximized to allow proper air circulation in poultry houses. Air movement helps in the removal of built-up ammonia, carbon dioxide and moisture. Water loss in poultry through the lungs encourages panting of birds. It is recommended that more water be given to broilers during hot weather to prevent their body fluids from continuous dehydration.

Cool drinking water stimulates both feed and water intake. Reducing the body temperature of heat-stressed broilers is beneficial. When the temperature of drinking water is lower than body temperature, it will absorb the body heat. Therefore, providing adequate and cool drinking water is extremely important to heat-stressed broilers (Gary and Butcher, 2003). Anything that results in increased water consumption during heat stress will benefit the survival rate. In fact, more research on salt supplement will definitely attribute to the increased survival rates of heat-stressed broilers. The feeding supplements such as potassium bicarbonate, potassium chloride, sodium chloride and ammonium chloride will increase water consumption in broilers.

12.2.7 Environmental Design and Animal Well-being

Better environmental design and shelter are recognized as the basic need for poultry animals. This aspect is a critical issue in terms of both adequate care and economic value. In physical environment, shelter, space allowances, equipment, access to food and water, and protection or exposure related to terrain, trees, or other characteristics of the natural environment in any location where livestock are reared or managed, are necessary.

Food is another important element recognized as a basic need for birds. The essence of production system in poultry industries are divergent. It is important to design a well formulated feed intake methods to ensure for better performance and animal well-being.

Better understanding of the relationship between animals, their environmental and behavioural responses, social and psychological aspects are very important for producers.

Over the past decade, livestock producers in the world are increasingly aware of the importance of psychological well-being to the condition of animals and are now giving much greater consideration to it.

Housing of Poultry

Many poultry producers use a variety of different bird strain combinations in their management operations. It is becoming a common practice for a day old male chicks or cockerels to be raised separately from pullets. It is best to raise the young male chicks separately for at least the first few weeks before co-mingling them with the pullets.

A potential breeder is advised to design a pen suitable to raise chicks separately before they are mixed with each other. Bringing chickens together encourages cannibalistic practices, though the most extensive factors affecting feather pecking are the housing system. Fowls spend nearly 94% of their time foraging and eating (Dawkins, 1989), hence as the barren environment of battery cages does not offer enough stimuli, the outcome will result in high level of pecking in cages than in pens. The plumage status could be preferred on litter, as the presence of suitable substrate for foraging and dust-bathing (Blokhuys, 1989). It is accepted that birds reared in pens with slats of plastic grid showed more feather pecking than in pens with litter (Aerni et al., 2000; Huber et al., 1997; Huber et al., 2001a). The plumage condition is better in the presence of perches during rearing period (Huber and Wechsler, 1998). It has been reported by many authors that early experience in litter substrates will help reduce feather pecking in mature hens (Huber and Wechsler, 1997). Although some authors could not accept this phenomenon, it is presumed that this application will contribute in reducing feather pulling, if not totally stopping the habit.

Most poultry farmers believe that the provision of sand for dust-bathing could prevent birds from cannibalistic practices. This is not true, in order to clarify this concept, Huber and Wechsler (1997) wrote in their publication that the provision of chicks with a sandy area will only help in promoting playing areas, but will not prevent feather pecking, instead give room for the practice if they are not well fed. Feather pecking can be lowered among Brown and Lohman Selected Leghorn if they are reared under free-range systems. The free-range systems grant birds an opportunity to feed on different types of fresh grass, insects and even ants. They will not be subjected to hunger and the possibility of feather pecking will be minimal.

Poultry houses should be able to provide protection to birds from cold, rain, wind, and hot sun. They should also be able to provide warmth for birds during brooding period. The housing systems should provide protection from predators, as well as good ventilation to remove toxic ammonia, humidity, and carbon monoxide. Many innovative housing designs are mainly used in range poultry productions today and have been effective in providing their basic needs.

There are many types of field pens. The roofing is flat, peaked, domed, or hooped. Building materials used include wood, PVC, rebar, electrical conduct, and bamboo. Portable and stationary housing designs and materials also vary tremendously. The “best” type of construction and material may depend on the farmers’ skills (e.g., whether he has the skill to weld, etc.). There are both floored and floorless designs. Some have multiple popholes; others have entire sides that open up. Good housing should be able to provide at least 1 m² per bird. Birds spending much of the time outside during good weather need careful consideration when certified as an organic product; no treated wood is allowed to come in contact with such poultry. Most portable houses need to be staked or weighted down in strong winds. Insulation may be needed in the roof and sidewalls in cold areas.

A poultry hoop house can make a good shade hut for sheep, or winter storage for hay. Some hoop houses are designed to use solar energy in winter. The shade cloth can be removed to make a solar greenhouse during winter. The use of good quality materials in poultry house design is expensive but more durable. A well-designed structure prevents disease outbreak and improves the quality of production.

Mobile Housing

In the Netherlands, organic and free-range broilers are mainly housed in non-mobile houses. In the USA, Canada, and the UK, mobile housing is frequently used for these systems. The use of mobile houses can be attractive, because 16 birds/m² can be kept, instead of 10. The house can be moved to a clean site after each cycle. The disadvantage of this practice is that it is labour intensive, because of the transport of feed, litter and water. In mobile housing, the climate is very difficult to control and problems can occur with frozen water systems. Weiland gave a recommendation of this type of system. He recommended that moving the houses gives opportunities for birds to have fresh grass. He also mentioned that more birds might be victimized by predators, as birds in mobile houses have permanent access to an outdoor run. In non-mobile houses, the main advantage is that the system can be automated easily. The disadvantage is the more difficult management of the outdoor run. Hans-Dieter Wilczack advised that the outdoor run should be covered with fresh grass to avoid the problem of diseases. However, it would be necessary to move the birds to a different outdoor run from time to time in order to ensure that the outdoor run stays empty for a period of time between cycles (Lampkin, 1997).

12.2.8 Housing Environment and Disease Prevention

It is generally true that if producers maintain proper house temperature and air quantity, the chance of respiratory disease will be reduced. Even if

respiratory challenge does occur, the severity can be lessened through good environmental management.

When looking at good environmental management, it actually refers to taking control of the environment to avoid all the obnoxious diseases. In the absence of adequate environmental control, producers will have less control over this respiratory disease and may result in a serious outbreak of respiratory disease. Increasing ventilation rates provides better air quality for birds without sacrificing house temperature. This will provide the birds with more opportunities to thrive well in their environment.

Ventilation

The performance of broilers and other types of chicken depends on the available air quality. Chicks, for example, require a minimum of 100% air exchange rate six times a day. In any poultry management system, air inlet should be a basic criterion for a sound management practice. Inlets are necessary for controlling direction of air and its velocity. In cold weather, air entering through inlets is instrumental in blending the outside air with warm air inside, so that fuel is conserved and the accurate temperature is maintained within the poultry environment. The problem most often encountered with poor air movement is sinusitis. Sinusitis is a direct result of excess humidity and ammonia released from manure. *Ammonia leads to irritation in the respiratory tract of birds, which causes tissue scarring and decreasing oxygen diffusion into the blood stream.* Both sinusitis and ammonia scarring retard the growth weight of fowls, which leads to economic loss. Sinusitis and ammonia can be controlled by providing quality air management for better fowl production.

12.2.9 Health Management

Animal diseases have increasingly been accepted as natural disasters both in their own right and as consequences of other disasters. In view of the increasing frequency of disease emergencies, it is necessary to develop systems for their prediction, early detection, and structured risk-based surveillance leading to early warning. This, in turn, should be able to lead to an organized and structured response in order to control disease outbreak and prevent it from evolving into a major epidemic. It is equally important to address a disease at source, where it is ordinarily endemic, in order to reduce its impact on food security, on the vulnerability of poor communities and to reduce the risk of spread from endemic areas to free areas causing serious disasters. This is the basic principle which underpins poultry production programmes, whose vision is stated as: "To promote the effective

containment and control of the most serious epidemic livestock diseases as well as newly emerging diseases by progressive elimination on a regional and global basis through international co-operation”.

Therefore, in addressing animal diseases as a natural emergency, experts have developed a guide to help poultry farmers establish a structured approach to disease emergencies. In the International Animal Health, the following are explained: structures and resource management leading to early detection of disease or infection in an animal population, prediction of the likely spread, prompt limitation, targeted control and elimination with subsequent re-establishment of verifiable freedom from infection. In recognizing disease approaches, its emergence generally occurs in four main segments:

- Planning for an emergency
- Recognizing an emergency
- Responding to an emergency
- Recovering from an emergency

The programme is underpinned by a set of resource materials as videos, manuals, photo-library, model contingency plans and has links to major internet sites dealing with disease emergency management.

Finally, it should be noted that to resolve the problems faced with the dilemma of the need for sustainable agricultural production, the desire for increased and liberalized trade and the threat of infectious diseases should be an important factor for consideration. The World Food Summit held in Rome in 1996 entrusted world leaders and civil societies with the task of ensuring effective prevention and progressive control of plant and animal pests and diseases, especially those of trans-boundary nature, such as Newcastle Disease of Poultry, Rinderpest of cattle, Cattle Tick, Foot and Mouth Disease and Desert Locust, which if they breaks out can cause major food shortages, destabilized markets and trigger trade measures, and promote concurrent exigency plans. Regional collaboration in plant pests and animal disease control, and the widespread development of the use of integrated pest management practice, will help in diseases and pests control, and promote food production and security. When these factors are seen as hindrance to food production, then scientists will have a greater role to play in finding the best possible solutions to the eliviation.

Debeaking

Most American poultry industries and egg producers use battery cages and crowded floor management systems. In the management, half to two-thirds of birds' beaks are removed to avoid “cannibalistic practices” and “feather

pecking". Feather eating and cannibalistic practice are abnormal behaviour among domesticated fowl kept in a close, crowded confinement. However, this practice of debeaking is highly discouraged in an organic farming system due to the simple reason that debeaking changes the physical appearance of birds and causes serious pain to them, which affects their welfare and leads to inability of the birds to express their natural behaviour.

Debeaking, as mentioned by Landner (2004), has been scientifically demonstrated to be very painful and may result in lifelong abnormal behaviour in birds. Birds have a thin bone between their horn and it is a highly sensitive soft tissue. The hot iron used for debeaking usually cuts through this complex horn, bone, and sensitive tissue, causing severe pain and forming tumours in the healed beak stump. Considering animal welfare, debeaking causes the inability of chicken to feed, drink and preen effectively, and may lead to behavioural disorders, which are associated with chronic pains and depression. This will eventually lead to poor quality egg production and also lower productivity.

A publication by Appleby (1991) on the suffering of hens in battery cage systems states that "The main injury caused by humans, knowingly rather than accidentally, is beak trimming". Debeaking has been identified as serious practice that causes a severe pain to birds not only in the short term, but also has an adverse effect in the long term.

Plans are currently underway to stop debeaking of birds. The 1991 plan of action of the British Farm Animal Welfare Council Report on the Welfare of Laying Hens in Colony Systems pointed out that the neglect of animal welfare is a serious insult to hens if it continues to be practised. It was also suggested that a well managed system, leading to the fulfilment of all the basic requirements necessary for hen production, will help in the formation of a proper management scheme in the long run (Karen, 2004). The trimming or amputation of beaks in chickens and turkeys is a bad practice. It is a sign of poor management by the breeders.

Trimming disfigure birds and deprive them of their natural behaviour and rights. Debeaking is quite different from trimming one's fingernails. Trimming of fingernails is a way of avoiding germs deposited on the fingers from entering the food to be eaten with our hands. However, in poultry, the case is different; it is a sort of insult to their welfare. Several debates and seminars have been organized on ways of eradicating beak amputation, in a real sense, debeaking should not be practised as it deprives birds from feeding efficiently. Besides, grit is added to their feed. The absence of the beak will result in their inability to pick up grit.

Recent evidence from research on beak trimming has suggested that genetic selection may also be used to decrease the incidence of cannibalism among flocks housed together.

12.3 CATTLE PRODUCTION

In the mid-1970s, about 7 million *Bos taurus* cattle, including 4.8 million *N'Dama*, and 2.2 million *West African shorthorns*, were found in large multitudes in the more humid southern regions, the trypano susceptible *Bos indicus* breeds were found in large numbers in the drier northern region covering the Sahel, and most of the 3 million cross-breed populations were found in the boundary area between the two regions (ILCA/FAO/UNEP, 1979).

Present study on livestock does not focus on regions where most of the different breeds are located instead focuse on a boundary area because interbreeding and genetic introgression is most likely in the areas and farmers in these areas are more likely to have information about the advantages and disadvantages of different breeds and the option of bringing different breeds into their herds.

In order to understand different zones suitable for cattle in southern Nigeria, the derived savannah ecozone—a transition zone between humid and sub humid zones—of Oyo State, was chosen because most of the cattle in southern Nigeria are located in this area. The different breeds of cattle mainly found in this region are the Muturu—a *trypano tolerant Bos taurus* breed; White Fulani—a *trypano susceptible Bos indicus* breed; Keteku—a stabilized cross between Muturu and White Fulani; and N'Dama—a trypano tolerant *Bos Taurus* breed, which was introduced into the region through breed improvement programmes in early 1970s.

In 1959, there were about 65,000 cattle in southern Nigeria, most of which were Muturu and Keteku breeds, today the number has increased immensely. The cattle population increased to about 100,000 during 1974/75, to 140,000 in 1984, and to 234,000 in 1990 (RIM, 1992; Blench, 1994) but the exact record of numbers could not be traced during this research. Current investigation has shown that the number of trypanotolerant cattle in the Southern region—particularly with Muturu and Keteku, has decreased. The number of Muturu cattle in Nigeria has decreased from about 200,000 in 1938 to between 60,000–115,000 in the recent years (Hoste et al., 1992; Akinwumi and Ikpi, 1985) and new breeds have been identified through genetic improvement.

Between 1980 and 1983, 5,000 N'Dama were imported from The Gambia to Nigeria as breeding stock. The number of these stocks was multiplied and disseminated from five government ranches in the southern part of the country. The total number of N'Dama in the country increased from 14,800 in 1975 to 24,800 in 1984 (ILCA/FAO/UNEP, 1979; Hoste et al., 1992). Though N'Dama were raised as multi-purpose animals in The Gambia, the

early adopters of the N'Dama in southern Nigeria raised these animals primarily for beef (Jabbar et al., 1995).

The major livestock development activity in The Gambia started around 1933 and it was mainly centred on controlling crucial diseases of cattle. However, by the early 1970s, most of the important contagious diseases of cattle were either eradicated or kept under control. This situation led to the steady increase of the cattle population from 100,000 in 1850 to 300,000 in 1977/78. Due to various factors such as high population pressure and limitations in terms of access to grazing areas and watering points, the population has since stabilized around this figure.

A survey carried out in Kumasi (Ghana) in 1999 has shown that the majority (93%) of the cattle population was kept by cattle rearers. 56% of sheep and goat were owned by northerners; pig production is still comparatively very small. The survey shows that the animals are suffering from rapid decline of grazing land. The number of people engaged in pig production in the northern part of Ghana is relatively very low. This is a result of Muslim dominance.

12.3.1 Environmental Condition

Competition from productive zebu cattle restricts the ecological habitat of trypano tolerant cattle to the tsetse fly infested zones where the zebu cattle cannot survive. As a result, the single most important factor determining the distribution of trypano tolerant cattle in different regions of West Africa is the distribution of tsetse flies. This distribution is, however, closely related to geographical relief, hydrography, climatic conditions and the prevailing vegetation.

The International Livestock Control Agency (1979a) once presented a summary description of some of the features of the West African region where trypano tolerant livestock are found. It was described that the northern limit of the areas where this infestation is rampant, is considered to have 750 mm and 1,500 isohyets, above which is the dry, tsetse-free Sahelian zone. Isohyets is a transition climate and the rainfall and vegetation can be divided into a Sahelo-Sudanian zone to about 1,250 mm and a Sudano-Guinean zone from 1,250 to 1,500 mm.

12.3.2 Ecological Settings for Dwarf Muturu

The distribution of the Ghana Shorthorn indicates that its habitat is not limited to the savannah regions alone, despite the fact that it is classified as a Savanna Shorthorn. The Guinean savannah woodland area in Ghana

located north of the forest zone, stretches down to the south eastern plains. It comprises a continuous cover of grass and low fire-resistant trees. The typical trees include *Parkia* spp., *Jacarand* spp. and *Butyrospermum parkii*. There is a single rainy season from March to October in the northern half of the country during which 1,000 to 1,200 mm of rain falls annually. Temperatures are very high with a mean annual maximum of 34.5°C in the extreme north. The humid rain forest in the southwest of Ghana receives an average rainfall of between 1,210 and 3,312 mm annually. The other forests are semi-deciduous with a bimodal rainfall pattern and mean daily maximum and minimum temperatures of 30° and 21°C, respectively. The coastal savannah of Ghana receives an annual rainfall of 800 to 1,000 mm between April and November. During the dry seasons (November and March), maximum daily temperatures can be as high as 32.2°C. Mean monthly relative humidity is about 70% at 15.00 h (GMT).

Andropogon, *Brachiaria* and *Hyparrhenia* spp. are the most common grass types of the coastal savannah. The south eastern part of this area, near Ada and Keta Lagoon is the habitat of the few *Dwarf Muturu* cattle in Ghana. However, this is an unusual location for animals whose size is usually associated with a forest habitat.

The Muturu's present location in Nigeria is the forest zone and Guinea savannah of the Middle Belt (Adeniji, 1985). The **Dwarf (Forest) Muturu** is found in the rain forest (Rouse, 1970; Olutogun, 1976; Fricke, 1979) just north of the coastal mangrove swamps, but a few hundred Muturu were reportedly found in the swamps of the states of Cross River, Edo, Ondo, Ogun, Lagos (ILCA, 1979b) and Rivers (Akinwumi and Ikpi, 1985). The coastal forests, located south of the seventh parallel in the west and below the sixth parallel in the east have constantly high temperature—ranging from 26 to 28°C—and high humidity, with an annual rainfall of between 1,800 and 3,000 mm. The rainy season lasts from seven to eight months between May and December, interrupted in August by a short dry season that becomes less distinct towards the south and disappears along the coast where there is virtually daily rainfall.

The habitat of the *Nigerian Savanna Muturu* is the "derived" savannah, and the Guinea savannah which covers a narrow belt between the Guinea savannah to the north and the rain forest to the south, has a climax vegetation created by the destruction of the original forest cover through constant shifting of cultivation and population pressures (Olutogun, 1976) located in the higher rainfall belt of the country, which is derived from savannah natural grassland. The grass varieties found in the region are the annual grass like *Brachiaria deflexa* and *Digitaria horizontalis*, which are among the first species to appear after the original forest is cleared. Perennial

grass varieties also include *Pennisetum purpureum*, *Panicum maximum*, *Ctenium newtonii*, *Andropogon tectorum* and *Hyparrhenia rufa*, which appear later.

The Guinea savannah of the region usually receives an average rainfall of 1,500 to 2,000 mm, while the surrounding plateau and plains receive 1,000 to 1,500 mm, and the drier west receives 500 to 1,000 mm. The region is, however, characterized by tall perennial grass (1.5 to 3.0 m high) such as *Andropogon* and *Hyparrhenia* that grow in tussocks and provide wide ground coverage. The type of grass found in this region is dictated by soil moisture. Dry soils are dominated by plant associations with *Loudetia arundinacea*, *Ctenium newtonii* and *Monocymbium ceresii*, while damp soils support grass types such as *Pennisetum purpureum*, *Chloris*, *Robusta* and *Brachiaria* spp.

The habitats of both Muturu types (Forest and Savannah) fall within the tsetse fly belt. *G. fusca* is associated with the coastal forest, while the *morsitans* and *palpalis* groups are found in the savannah areas.

In Liberia, the main habitat of Muturu is the eastern coastal areas of Maryland and Sinoe counties and farther inland in Grand Gedeh and Bong. The whole country has a humid tropical climate and forest vegetation. The low coastal belt, about 80 km wide, receives over 5,000 mm of rainfall (Jeune Afrique, 1973; ILCA, 1979b) and is well watered by shallow lagoons, tidal creeks and mangrove marshes. The average annual temperature is 27°C with a mean maximum of 37°C and minimum of 10°C. Behind the coastal belt lies an undulating plateau 500 to 800 m above sea level that is partly covered with grass and dense forests. From the Inland and to the north is the mountain area which is also covered by forests. Long rainy seasons between May and November alternate with dry seasons from November to December and April to May. Most precipitation is received in June and September. The whole of Liberia is in the tsetse fly-infested zone. *G. palpalis*, *G. pallicera* and *G. fusca* are widely distributed, while *G. medicorum* is found in the south.

12.3.3 Management and Production Systems

Ghana Shorthorns are poor milkers (Maule, 1990) and are generally not milked (Ngere, 1974). Montsma (1960) mentioned that milk yield of Ghana Shorthorns is too low to warrant the sale of fresh milk without adverse effects on the growth and general well-being of the calf. When Ghana Shorthorns is milked in the absence of calf, they go dry within a few weeks (Ngere et al., 1975). The breed has good conformation for meat production. Though, it yields reasonable beef carcasses and may be used as a draught animal.

Over 99% of all Ghana Shorthorns are kept in village herds (Straw et al., 1987). Most cattle owners in Ghana are resident farmers, but town dwellers are increasingly becoming absentee cattle owners using hired herders, usually the Fulani people. In such situations, the herders milk the animals, which forms a large part of their salary. Cattle are grazed on communally owned land (Cockcroft, 1977). In many cases, especially in the main livestock region in the north, animals of several households are herded together and tended by village children, partly because the animals are good-natured, and are penned at night. In the southeast, a herd may be allowed to graze on a farmer's land in exchange for the manure produced. In northern Ghana, herd sizes are usually small, of which most are family owned of about 5 to 20 herds of cattle. A high percentage of oxen population in the region are kept in areas where they are used for the purpose of ploughing soil for crop cultivation.

Muturu

Muturu are generally not milked (Ross, 1944; Fricke, 1979; Ngere, 1990) since their yield is just sufficient for their calves. In southern Nigeria, milk is extracted from Muturu by *native doctors for medicinal preparations*. The animals and their hides are used mainly for ritual sacrifices and ceremonies (Fricke, 1979), particularly funerals (ILCA, 1979b). When a pagan dies, for example, one or more oxen are sacrificed and the corpse is rolled up in the hides of the slaughtered animals, while the meat forms part of the ceremonial feast. Occasionally, Muturu cattle are slaughtered specifically to provide meat (Ferguson, 1967; Domingo, 1976; Fricke, 1979).

Muturu are used for draught in some areas (Domingo, 1976; Adeniji, 1985), though they are not commonly used as work animals. Some villages own only a few herds, which scavenge around the huts (Rouse, 1970). Muturu are commonly kept as pets (Ross, 1944; Rouse, 1970) or, frequently, they are used for prestige or dowry purposes (Ross, 1944). Manure is collected only occasionally from the field where the animals are kept.

Due to a wide distribution of Muturu in Nigeria, it has become difficult to make general statements about management practices, which range from permanent confinement with stall-feeding, through tethering, to year-round grazing. Grandin (1980) gave a detailed description of the Muturu-keeping systems found among the Egun people in the 1970s, but significant changes have occurred in these systems since then. Akinwumi and Ikpi (1985) also made a comprehensive presentation of the production systems of the Muturu in Nigeria. The Resource Inventory and Management Ltd presented a detailed coverage of management systems of Muturu in different regions of Nigeria in the recent publication (RIM, 1992). The presentations indicate

and lay emphasis on a wide variation of management systems of herding, feeding and housing methods. It was mentioned that the availability of labour and access to grazing land has been overridden, which is the main determinant of the type of husbandry system used in production. On the one hand, expanding cultivation in many areas, especially in Igboland—eastern Nigeria, either has tended to discourage the keeping of Muiuru or has forced owners to turn to stall-feeding or tethering systems. On the other hand, some of the northern Muturu populations, such as those in the northeast and on the Dimbuk escarpment, have ready access to mountain pastures that are of no value as arable land and can, therefore, be grazed by cattle with little supervision without risk of damage to crops.

In Igboland, about 45% of the herds are taken out to graze, 45% are tethered, and 10% are permanently stall-fed. The animals are kept in enclosures surrounded by hedges (*oka-efi*) with built-in sheds for shelter during the night or in bad weather. Traditionally, these cattle were considered sacred (*juju* cattle) in this region and were the property of local deities or were dedicated to the shrine. With the decline in tradition and the destruction of shrines, many villages are without a bull, which threatens the survival of these cattle populations.

Most Muturu in southern Nigeria are in the hands of private owners, whether individuals, communities or traditional chiefs and royal families. The animals receive little care and largely survive by scavenging around the village. They are usually seen grazing and sleeping in the fields of community schools. Where the animals are communally owned, rampant superstitions limit their control and they are often allowed to roam about, destroying crop farms. Aggrieved crop farmers are not permitted to harm them. In some areas, cattle ownerships are limited to traditional rulers and highly placed chiefs from whom permission must be sought before an animal is killed.

The Muturu village production systems can be classified into three broad groups: free-range, household (compound) and communal (cooperative). In addition to these, there are a few government stations such as Ado Ekiti, Imala and Odeda where Muturu are kept (Akinwumi and Ikpi, 1985). The free-range system has been associated with the "wildness" of the Muturu (Epstein, 1971; Fricke, 1979; Akinwumi and Ikpi, 1985). Household production systems are characterized by the provision of a shed and stall-feeding. Common feeds used in this system include cassava leaves, chopped tubers, yam peels, maize on the cob, fresh maize leaves, kola nut pods and salt. Limited grazing on the compound is also possible. Under this system, animals grow quite fat when feeds are abundant. Such herds tend to have no bulls, and breeding is usually a problem.

The communal production system is common in the states of Ondo and Rivers in Nigeria. In Rivers State, the usual system of management is to allow the cattle to range freely throughout the year. In many cases, cattle are owned by the community and cannot be slaughtered without permission from elders or a special committee. The semi-feral animals are not milked. They receive little veterinary care and are not given any supplementary feed. Little attention is paid to their breeding. These factors, in addition to the importation of zebus from the north, make the disappearance of Muturu from Rivers State almost inevitable. More organized communal systems also exist, however, where owners pool their animals, often uniquely tagged, and engage one or two Fulani herders. A tract of land is set aside within the village for housing. Local government authorities occasionally provide a kraal within which improved pastures are developed and made available at a fee to the cattle owners. This system was adopted in response to the persistent agitation of crop farmers over the destruction of their crops and has had contrasting consequences in different states.

In Ondo State, the acceptance of this system has essentially ensured the survival of Muturu, while in adjacent Edo State, several communities are forced to slaughter their cattle as a result of constant pressure from farmers of arable crops. This partly explains the decline in the Muturu population in this state between 1977 and 1984.

The Muturu in Liberia are also kept under village conditions, although commercial production is being initiated on the rubber plantations of the Liberian Agricultural Company and Firestone, as well as on private commercial farms. Under village conditions, these animals are rarely herded and receive very little care. In some cases they are tethered to avoid crop damage.

Recommendation

In recommending the best methods of farming to farmers, the need to encourage donors to participate in implementing programmes relating to soil fertility at both national and international levels should be one of the requirements. There is need to include universities and research institutions in plans and programmes involved in agricultural development. When seeking donors' involvement, it should be noted that different donors have different comparative advantages in relation to providing technical assistance and funding of agricultural projects. Governments of different nations should be involved in agricultural expansion as there is a growing recognition amongst policy makers and specialists.

Degradation of soil is one of the root causes of declining agricultural productivity in Sub-Saharan Africa and other parts of the world. The control

of degradation should be a major focus of scientists. There should be projects organized by institutions, universities and private sectors geared towards remineralization of the lost nutrients. Awards should be given to interested individuals based on merit, to investigate factors leading to demineralization and possible solutions.

Farmers should be cautious of nutrient usage by plants and animals. Surplus nutrients in the soil might result in nutrient losses, which may subsequently lead to water and air contamination and eutrophication of the farming environment. There should be a farm design programme to educate farmers on the amount of nutrients required by plants at different levels. The programme should focus mainly on organic substances as nutrients availability to plants and usage determines plant performances, yield and quality.

The quantity, quality, and performance of livestock are based largely on nutrition. Quality of livestock is related to the mineral content of the feed grown, which is dictated primarily by the natural mineralogy of a given soil and historical fertilizer inputs (Boom, 2002). Within the framework of pastoral organic beef farming, there is always the ability to change the mineral content of a soil where the animals are reared so that the feed grown will have the full range of macro and micronutrients within the specified requirements for optimum ranges for beef cattle. Due to the differences in plant nutrient requirements in comparison to livestock management, Boom explained that the level of some minerals, such as potassium and sulphur, found in pasture areas are commonly excessive to animal requirements. This can have a significant impact on the bioavailability of other elements like calcium and magnesium.

It is known that only few soils have all 17 essential elements required by both plants and animals in the right proportion. It is imperative to understand and correct the imbalances that occur at the soil level so that neither plant nor animal productivity is compromised. Trace element deficiencies can be addressed through their inclusion in the organic fertilizer regime, and are often applied to the soil in inorganic forms, their uptake via the plant roots and subsequent translocation to the foliage in highly available organic complexes is the most natural way of providing grazing livestock with necessary minerals (Boom, 2002).

To avoid the use of synthetic substances in production of crops, it is recommended that farmers use cattle urine in place of potassium, as it contains a very high amount of potassium due to the excess K found in pastures, that is above the needs of grazing cattle. The areas around the grazing and drinking trough in an animal house contain high amounts of urine. Producers should be aware that plants tend to luxury feed on

potassium if it is available in the soil, and if the exchange sites in the soil have a higher proportion than normal saturation, it can reduce the availability of other elements like calcium, magnesium, sodium and boron, as mentioned by Boom (2002) in internet publication. In the area where pastures with potassium levels are above 3.5%, the total dry matter is less palatable to cattle, and if consumption is lowered, the weight gain by cattle will be reduced.

Organic regulation requires the application of calcium as lime, dolomite, marl, industrial lime by-products such as basic slag, reactive phosphate rock, and gypsum. When it is applied to the soil in excess, it may reduce the availability of phosphorus and boron and other cations such as magnesium, potassium, iron, manganese, zinc and copper. It may as well lead to excessive high levels of molybdenum in the forage, which induces a copper deficiency in livestock. Boom recommended the addition of magnesium for the maintenance of organic soil. He singled out dolomite, limestone, magnesite or serpentine rock. Besides, the current move in organic agriculture favours the use of rock dust materials to remineralize soil within a short time.

To achieve the objective of the most healthy organically grown crops and animals, the knowledge of mineral content of crops grown and animals reared are very necessary. At present, no element is considered more important than the others. This has proved by a series of tests conducted on different elements, although different crops require different elements at different times, all the elements are needed by crops and animals for their complete growth and production. Therefore, the need to supply all the elements in reasonable proportion is highly imperative. The supply of nutrients will be appropriate when in natural form (organic) because of the interrelationship of all essential elements and their effect on one another, and also considering the hazard caused by synthetic elements. A deficiency or excess of any of the required nutrients may be critical in the life of plants grown in an environment.

References

- Abushita, A.A., Hebshi, E.A., Daood, H.G. and Biacs, P.A. (1997). Determination of antioxidant vitamins in tomatoes. *Food Chemistry*. 60.
- Adeniji, K.O. (1985). Review of endangered cattle breeds of Africa. In: *Animal genetic resources in Africa: high potential and endangered livestock*. 2nd OAU Expert Committee Meeting on Animal Genetic Resources in Africa, 24-28 November 1983, Bulawayo, Zimbabwe. Nairobi, Kenya, OAU/STRC/IBAR., 20-32.
- Agrawal, A.A. (1998). Induced responses to herbivory and increased plant performance. *Science*. 279.
- Agrios, G.N. (2005). *Plant Pathology*. 5th edition, Elsevier Academic Press, Burlington, MA, USA
- Akinsanmi, O. (1994). *Senior Secondary Schools Agricultural Science*. Longman Group, Malaysia.
- Akinwumi, J.A. and Ikpi, J.E. (1985). Trypanotolerant cattle production in southern Nigeria. Report to International Livestock Centre for Africa (ILCA) Humid Zone Programme, Ibadan, Nigeria. ILCA.
- Akinyemi, O.M. (2005). *New Poultry Production: The Case of American, British and German Systems*. Masters Thesis, University of Kassel, Germany, Published in Organic Eprints.
- Akinyemi, O.M., Blake, P., Hindo, N. and Shulz, K. (2005). The effects of organic and conventional management practices on soil characteristics, in particular aerobic nitrogen mineralization: Working paper in the faculty of soil microbiology (unpublished paper).
- Alemán, F. (2001). Common bean response to tillage intensity and weed control strategies. *Agronomy Journal*. 93(3).
- Alfoeldi, T., Fliessbach, A., Geier, U., Kilcher, L., Niggli, U., Pfiffner, L. Stolze, M. and Willer, H. (2002). Organic agriculture and the environment. In: El-Hage S.N. and Hattam C., eds. *Organic Agriculture, Environment and Food Security*, Chapter 2. Environment and Natural Resources Series 4. Food and Agriculture Organization of the United Nations (FAO).
- Altieri, M.A., Letourneaur, D.K. and Davis, J.R. (1983). Developing sustainable agroecosystems. *BioScience*. 33.

- Amaral, L.D. (2004). Drinking water as a risk factor to poultry health. Brazilian Journal of Poultry Science. Available at: <http://www.scielo.br/pdf/rbca/v6n4/23324.pdf>.
- Anderson, J.P.E. (1982). Soil respiration. In: Haney R.L. et al. (eds). Soil Carbon and Nitrogen Mineralization: Influence of Drying Temperature. Published in Soil Sci. Soc. A. m. J. 68.
- Anderson, J.P.E. and Domsch, K.H. (1975). Measurement of bacterial and fungal contributions to respiration of selected agriculture and forest soils. Canadian Journal of Microbiology. 21: 314-322.
- Anderson, T.H. and Domsch, K.H. (1989). Ratio of microbial biomass carbon to total organic carbon in arable soils. Soil Biology & Biochemistry. 21.
- Anonymous (2005). Systemic acquired resistance. Available at: <http://www.aber.ac.uk/plantpathol/sar.html>.
- Anonymous (1999). Product and Market Development by International Trade Centre, GENEVA. <http://www.intracen.org/mds/sectors/organic/bluebook.pdf>.
- Anonymous (2000). Hypersensitive response (HR) in tobacco leaf. American Phytopathological Society. <http://www.apsnet.org/online/feature/Genomics/Images/hrtobacco.htm>.
- Anonymous (2000). The state of food insecurity in the world. Published in 2000 by the Food and Agriculture Organization of the United Nations. ISBN 92-5-104479-1. Accessed on: 20.07.06 at: <http://www.fao.org/FOCUS/E/SOFI00/img/sofirep-e.pdf>.
- Anonymous (2001). Onion Cultivation. Accessed July 12th 2006. <http://www.avrdc.org/LC/onion/practices.html>
- Anonymous (2001). Organic Consumer Trends. Published by the Natural Marketing Institute and Organic Trade Association (OTA).
- Anonymous (2001). World Markets for Organic Fruit and Vegetables—Opportunities for Developing Countries in the Production and Export of Organic Horticultural Products. Published by FAO, Rome. Available at: <http://www.fao.org/DOCREP/004/Y1669E/Y1669E00.HTM>.
- Anonymous (2001). World Markets for Organic Fruit and Vegetables. FAO/ITC/CTA joint publication, Rome. http://www.cta.int/pubs/world_markets/summary.pdf.
- Anonymous (2002). World Horticultural Trade and US Export Opportunities, January. Available at: <http://www.fas.usda.gov/http/circular/2002/02-01/Stats/organic.pdf>.
- Anonymous (2002). World summit on sustainable development in Johannesburg. 26th August to 4th September 2002.
- Anonymous (2003). Current market situation and medium-term prospects by Food and Agriculture Organization of the United Nations. Unpublished Article.
- Anonymous (2003). Defence related proteins, division of medical devices. <http://dmd.nihs.go.jp/latex/defense-e.html>.

- Anonymous (2005). First-Year Effect of Organic and Conventional Management Practices on Selected Soil Quality Indicators at the Neely-Kinyon Farm, Greenfield, Iowa. <http://www.extension.iastate.edu/Publications/PM1882.pdf>.
- Anonymous (2005). Soil Formation and Classification. United States Department of Agriculture. National Resources Conservation Services. Available at: <http://soils.usda.gov/education/facts/formation.html>.
- Appleby, M.C. (1991). Do Hens Suffer In Battery Cages? The Athene Trust. Petersfield, UK.
- Appleby, M.C., Hughes, B.O. (1991). Welfare of laying hens in cages and alternative systems: environmental, physical and behavioural aspects. *World Poultry Science Journal*. 47: 109-128.
- Asmal, K. (1995). Forest Policy Discussion, Minister of Water Affairs and Forestry, Republic of South Africa.
- Atterholt, C.A., Delwiche M.J., Rice R.E. and Krochta J.M. (1999). Controlled release of insect sex pheromones from paraffin wax and emulsions. *Journal of Controlled Release*. 57.
- Audus, L.J. (1970). Symposium summary. In: Hill, S.B. (ed.) *Pesticides in the Soil: Ecology, Degradation and Movement*. Michigan State Univ. East Lansing in *Agricultural Chemicals and Soil* (1977). pp. 142-144.
- Babu, S.C. and V.J. Quinn. (1994). Food security and nutrition monitoring in Africa. *Food Policy*. 19 (3).
- Baldwin, K. R. (2001). Soil Fertility for Organic Farming. Assessed on the 26th July 2006 at: http://www.ncsu.edu/organic_farming_systems/news/soil_fertility.pdf.
- Bärberi, P. (2002). Weed management in organic agriculture: are we addressing the right issues? *Weed Research*. 42(3).
- Barnes, J.P. and Putnam, A.R. (1983). Rye residues contribute weed suppression in no-tillage cropping systems. *J. Chem. Ecol.* 9: 1045-1057.
- Barret, H.R., Browne, A.W., Harris, P.J.C. and Cadoret, K. (2002). Organic certification and the UK market: organic imports from developing countries. *Food Policy*. 27.
- Bates, T.R., Dunst, R.M., Taft, T. and Vercant, M. (2002). The vegetative response of 'concord' grapevines to soil pH. *Horticulture Science*. 37(6): 890-893.
- Bationo, A. and Mokwunye, A.U. (1991). Role of manures and crop residue in alleviating soil fertility constraints to crop production: With special reference to the Sahelian and Sudanian zones of West Africa. *Nutrient Cycling in Agroecosystems*. 13 (1).
- Beach, E.D. and Carlsson, G.A. (1993). A hedonic analysis of herbicides: do user safety and water quality matter? *American Journal of Agricultural Economics*. 73: 612.
- Beck, B. and Quigley, M.F. (2001). *Intensive Organic Gardening*. Department of Horticulture and Crop Science, Ohio State University Extension. Accessed on the 24th of May 2006 (<http://ohioline.osu.edu/hyg-fact/1000/1257.html>).

- Besong, J.B. (2005). Best options for securing the future of African rainforest: Theme 2: Participatory approaches to forest management. Published by Earth Watch Institute, Europe. Available at <http://www.earthwatch.org/site/pp.asp?c=crLQK3PHLsF&b=479765>.
- Besong, J.B. and Ngwasiri, C.N. (1995). The 1994 Forestry Law and National Natural Resources Management in Cameroon". A PVO-NGO/NRMS Cameroon Publication.
- Bjerklie, S. (1995). On the horns of a dilemma: The US meat and poultry industry. In: Stull D.D., Broadway D.J. and Griffith D. eds. Any Way You Cut It: Meat Processing and Small-Town America. University Press of Kansas, Lawrence, USA.
- Blench, R.M. (1994). The Expansion and Adaptation of Fulbe Pastoralism to Subhumid and Humid Conditions in Nigeria. *Cahiers d'études africaines*. 133-135.
- Blokhuis, H.J. and Wiepkema P. R. (1998). Case Studies of feather pecking in poultry. *Vet Quart*. 20: 6-9.
- Blowfield, M. (1999). Ethical Trade: A Review of Developments and Issues. Unpublished Report for NRI, University of Greenwich, UK.
- Boom, R. (2002). Healthy soil, healthy grass, healthy stock—the balance approach: First Virtual Global Conference on Organic Beef Cattle Production; organized by University of Contestado—Concordia Campus, Brazil.
- Bowden, R.L. (2000). Effects of Reduced Tillage on Wheat Management, Department of Plant Pathology, Kansas State University, Kansas, USA.
- Bramwell, K.R. (2005). Basic Concepts and Current Challenges in Managing the Modern Broiler Breeder. Published by the Department of Poultry Science, University of Arkansas, Fayetteville, Arkansas 72701, USA.
- Broady, P. A. (1981) The ecology of chasmolithic algae at coastal locations of Antarctica. *Phycologia*, 20, p. 259
- Brookes, P.C., Landman, A., Pruden, G. and Jenkinson, D.S. (1985). Chloroform fumigation and the release of soil nitrogen: a rapid direct extraction method for measuring microbial biomass nitrogen in soil. *Soil Biol Biochem*. 17: 837-842.
- Brouwer, J., Fussell, L.K. and Herrmann, L. (1993). Soil and crop growth micro-variability in the West African semi-arid tropics: a possible risk-reducing factor for subsistence farmers. *Agric. Ecosyst. Environ*. 45.
- Brouwer, J., Powell, J.M., (1998). Increasing nutrient use efficiency in West-African agriculture: the impact of micro-topography on nutrient leaching from cattle and sheep manure. *Agric. Ecosyst. Environ*. 71: 229-239.
- Brown, A.S.M. Cook, H.F. and Lee, H.C. (2000). Topsoil characteristics from a paired farm survey of organic versus conventional farming in southern England. *Biological Agriculture and Horticulture*. 18: 37-54.
- Buerkert, A., Mahler, F. and Marschner, H. (1996). Soil productivity management and plant growth in the Sahel: Potential of an aerial monitoring technique. *Plant and Soil*. 180: 29-38.
- Buol, S.W. (1995). Sustainability of Soil Use. Annual Review of Ecology and Systematics. Vol. 26. Soil Science Department, North Carolina State University.

- Cabrera, M.L. and Kissel, D.E. (1988). Potentially mineralisable N in disturbed and undisturbed soil samples. *Soil Sci. Soc. Am. J.* 52.
- Carter, M.R. and Rennie, R.A. (1982). Changes in soil quality under zero tillage farming systems: distribution of microbial biomass and mineralizable C and N potentials. *Canadian Journal of Soil Science.* 62.
- CGIAR (2001). South Africa Host Mid-term meeting. Available at: <http://www.worldbank.org/html/cgiar/newsletter/jul01/cgnews0107.pdf>
- Chander, K., Dyckmans, J., Hoeper, H., Joergensen, R.G. and Raubuch, M. (2001). Long-term effects on soil microbial properties of heavy metals from industrial exhaust deposition. *Journal of Plant Nutrition and Soil Science.* 164: 657-663.
- Clark, L.R., Geier, P.W., Hughes, R.D and Morris, R.F. (1974). *The Ecology of Insect Populations in Theory and Practice.* Methuen, Lond. Kluwer Academic Press.
- Clark, S., Klonsky, K., Livingston, P. and Temple, S. (1999). Crop-yield and economic comparisons of organic, low-input, and conventional farming systems in California's Sacramento Valley. *American Journal of Alternative Agriculture.* 14(3).
- Clarke, A.C. and Hodges, R.D. (1987). The environmental effects of conventional and organic/biological farming systems. *Biological Agriculture and Horticulture.* 4: 309-357.
- Cockcroft, F.L. (1977). *Agricultural Development Planning Project: Ghana Meat Development Project.* A UNDP FAO Consultancy Report. Rome, Italy.
- Collier, T. and Van Steenwyk, R.A. (2004). *Critical Evaluation of Augmentative Biological Control: Department of Environmental Science, Policy and Management. University of California, Berkeley, CA, USA Department of Renewable Resources, University of Wyoming, Laramie, WY, USA, Biological Control.* 31.
- Conroy, D.W. (1945). Legal Aspects of Land Holding Among the Tonga. In: Allan, W. et al., *Land Holding and Land Usage Among the Plateau Tonga of Mazabuka District: A Reconnaissance Survey,* Manchester University Press.
- Cordier, C., Pozo, M.J., Barea, J.M., Gianinazzi, S. and Gianinazzi-Pearson, V. (1998). Cell defense responses associated with localized and systemic resistance to phytophthora parasitica induced in tomato by an arbuscular mycorrhizal fungus. *MPMI* 11:1017-1028 <http://www.apsnet.org/mpmi/PDFS/1998/0706-02R.pdf>.
- Creamer, N.G. and Baldwin, K.R. (1999). Summer Cover Crops. HIL-37. Department of Horticultural Science, North Carolina State University, Raleigh, NC, <http://www.ces.ncsu.edu/depts/hort/hil/pdf/hil-37.pdf>.
- Creamer, N.G., and Baldwin, K.R. (1999). Summer Cover Crops. HIL-37. Department of Horticultural Science, North Carolina State University, Raleigh, NC, <http://www.ces.ncsu.edu/depts/hort/hil/pdf/hil-37.pdf>.
- Crowe, A.S. and Mutch, J.P. (1994). An expert systems approach for assessing the potential for pesticide contamination of ground water. *Ground Water.* 32: p. 487.
- Cruse, R.M. (2001). *Strip Tillage Effects on Crop Production,* Department of Agronomy, Iowa State University, USA.

- Davis, K. (2004). The Need for Federal Legislation Prohibiting the Inhumane Practice. <http://www.all-creatures.org/articles/egg-debeaking.html>.
- Dawkins, M.S. (1989). Time budgets in red junglefowl as a baseline for the assessment of welfare in domestic fowl. *Appl. Anim. Behav. Sci.* 24: 77-79.
- Dean, M., Motes, J. and Schatzer, R.J. (1987a). Commercial Production of Fresh Market Tomatoes. OSU Extension Facts No. 6019. Cooperative Extension Service, Oklahoma State University, USA.
- Dean, M., Motes, J. and Schatzer, R.J. (1987b). Commercial Production of Fresh Market Tomatoes. OSU Extension Facts No. 6019. Cooperative Extension Service, Oklahoma State University, USA.
- DeBach, P. (1964). *Biological Control of Insect Pests and Weeds*. Chapman and Hall, London.
- Delate, K. (2002). Soil Quality in Organic Agricultural Systems: Series 5 at physiologic maturity and the USDA-ARS Sustainable Agriculture Initiative, Iowa State University, USA.
- Delate, K. (2005). *Organic Agriculture*. Iowa State University, USA.
- Delate, K., Cambardella, C., Taylor, K. and Burcham, B. (1999). Comparison of organic and conventional rotations at the Neely-Kinyon Long-Term Agroecological Research (LTAR) site: First year results. Leopold Center for Sustainable Agriculture Annual Report, Iowa State University, Ames, IA.
- Dick, W.A. and Tabatabai, M.A., (1992). Potential uses of soil enzymes. In: Metting, B. ed. *Soil Microbial Ecology*, Marcel Dekker, New York.
- Diver, S. (1999). *Biodynamic Farming and Compost Preparation*. Published by ATTRA—National Sustainable Agriculture Information Service.
- Djajakirana, G., Joergensen, R.G. and Meyer B. (1996). Ergosterol and microbial biomass relationship in soil. *Biol Fertil Soils*. 22: 299-304.
- Domingo, P.M. (1976). Contribution à l'étude de la population bovine des Etats du golfe du Bénin. Ecole inter-Etats des sciences et de médecine vétérinaires de Dakar: p. 148.
- Doutt, R.L. and Hagen, K.S. (1949). Periodic colonization of *Chrysoperla californica* as a possible control of mealybugs. *Journal of Economic Entomology*. 42.
- Dumas M. (1997). Weathering of Rocks and Minerals. <http://www.usoe.k12.ut.us/curr/science/core/plans/int/rocks.html>
- Durrant, W.E. and Dong, X. (2004). Systemic acquired resistance. *Annual review of phytopathology* 42: 185-209. <http://www.arjournals.annualreviews.org/doi/full/10.1146/annurev.phyto.42.040803.140421>
- Edwards, C.A. (1965). Some side-effects resulting from the use of persistent insecticides. In: Hill, S.B., ed. *Agricultural Chemicals and the Soil*. EAP Publication-1.
- Edwards, C.A. and Thompson, A.R. (1973). Pesticides and the soil fauna. In: Hill, S.B. ed., *Agricultural Chemicals and the Soil*. EAP Publication-1.
- Ellis, R. H., Roberts, E. H. and Summerfield, R. J. (1988). Variation in the optimum temperature for rates of seedling emergence and progress towards flowering amongst six genotypes of faba bean (*Vicia faba* (L.)). *Annals of Botany*. 62: 119-126.

- Emmert, J.L. (2005). Modern Poultry Production. Arkansas State University, USA.
- Epstein, H. (1971). The Origin of the Domestic Animals of Africa. *Africana*, Vol 1. New York, NY, USA.
- Evan, E., (2000). Botanical insecticides. NC State University. Available at: http://www.ces.ncsu.edu/depts/hort/consumer/quickref/pest%20management/botanical_insecticides.html
- Evans, H.E. (1970). Life on a little known planet. In: Hill, S.B. ed., *Agricultural Chemicals and the Soil*. EAP Publication-1.
- Evans, L.T. (1993), *Crop Evolution, Adaptation and Yield*. Cambridge University Press, Cambridge, UK.
- Expert Consultation. (1999). Soil and Nutrient Management in Sub-Saharan Africa in Support of the Soil Fertility Initiative (SFI). Lusaka, 6-9 December 1999 conference.
- Fanatico, A. (2002). Sustainable Poultry Overview. Published by ATTRA, USA.
- FAO (1992). Food Balance Sheets. FAO Data Service, Rome.
- FAO (2002a). Land Tenure and Rural Development: ISBN 92-5-104846-0 (<ftp://ftp.fao.org/docrep/fao/005/y4307E/y4307E00.pdf>).
- FAO (1994). Production Yearbooks. Rome
- FAO (1994a). New Directions for Agriculture, Forestry and Fisheries, Strategies for Sustainable Agriculture and Rural Development. Rome.
- FAO (2002). Organic Agriculture, Environment and Food Security. SDRN, Rome Published article 2002 by FAO.
- FAO (2002). Water Source of Food Security. World Food Day: October 16th 2002.
- FAO (2003). Assessing of Soil Nutrient Balance: FAO fertilizer and plant nutrient bulletin ISBN: 0532-0488.
- Farrell, K., Flint, M., Lyons, J., Madden, J., Schroth, M., Weinhold, A., White, J., Zalom, F. and Jaley M. (1992). Beyond Pesticides, Biological Approaches to Pest Management in California. ANR Publications, University of California, Oakland, CA, USA.
- Firman, J.D. (1993). Nutrient Requirements of Chickens and Turkeys. A publication of the University of Missouri Extension. Accessed 17th July 2006 at: <http://muextension.missouri.edu/xplor/agguides/poultry/g08352.htm>.
- Foodnews (2003). Time to give your brand a health check. Leatherhead Food International. 37 (8).
- Frankenberger, W.T. and Dick, W.A. (1983). Relationship between enzyme activities and microbial growth and activity indices in soil. *Soil Science Society of American Journal*. 47.
- Franzluebbers, A.J., Hons, F.M. and Zuberer, Z.A. (1994). Long-term changes in soil carbon and nitrogen pools in wheat management systems. *Soil Sci. Soc. Am. J.* 58: 1639-1645.
- Freyer, B. (1997). Kennziffern der Nachhaltigkeit von 317 ackerbaubetonten Betrieben des biologischen Landbaus in der Schweiz, ausgewertet auf der Basis von Betriebskontrolldaten. In: Köpke, U. and Eisele, J.A. eds. *Beiträge zur 4. Wissenschaftstagung zum ökologischen Landbau*, Berlin. 103-106.

- Fricke, W. (1979). Cattle husbandry in Nigeria: a study of its ecological conditions and social-geographical differentiations. Heidelberg Geographischen Arbeiten. Geographisches Institut der Universität Heidelberg. 330.
- Friedmann, E. I. (1971). Light and scanning electron microscopy of the endolithic desert algal habitat. In: Hall and Otte, (Ed.). Biological Weathering on Nunataks of the Juneau Icefield, Alaska. Periglacial Processes, Vol 1: p 190.
- Friedmann, E. I. and Gulun, M. (1974). Desert algae, lichens and fungi. In Hall and Otte (Ed), Biological Weathering on Nunataks of the Juneau Icefield, Alaska. Permafrost and Periglacial Processes, Vol 1: p 190.
- Friedmann, E. I. and Weed, R. (1987). Microbial tracefossil formation, biogenous, and abiotic weathering in the Antarctic cold desert. Science, N. Y., 236, pp. 703-705.
- Friend, D.H. and Helson, V.A. (1988). Thermo periodic effects on the growth bud photosynthesis of wheat and other crop plant. Bot. Gaz. 137: pp. 75-84.
- Garcí-Gil, J.C., Plaza, C., Soler-Rovira, P. and Polo, A. (2000). Long-term effects of municipal solid waste compost application on soil enzyme activities and microbial biomass. Soil Biology and Biochemistry. 32.
- Gary, D. and Butcher, D.V.M. (2003). Ph.D., Professor and Poultry Veterinarian and Richard Miles, Ph.D. Poultry Nutritionist, College of Veterinary Medicine, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, USA.
- Geenzi, W.D. et al., eds. (1974). Pesticides in Soil and Water. Soil. Sci. Soc. Am., Madison, Wi. In: Hill, S.B (ed.). Agricultural Chemicals and the Soil. Ecological Agricultural Project.
- George, J., Nuttall, S.L. and Kendall, M.J. (2001). Prostate cancer and antioxidants. Journal of Clinical Pharmacy and Therapeutics. 26.
- Gerster, H. (1997). The potential role of lycopene for human health. Journal of the American College of Nutrition. 16.
- Ghani, A., Shah, M. and Khan, D.R. (1990). Response of rice to elevated rates of Zn in mountainous areas of Swat. Sarhad J. Agric. 6.
- Gilks, P. (1975). The Dying Lion: Feudalism and Modernization in Ethiopia. Julian Friedmann Publishing Ltd, London.
- Gold, M.V. (1999). Sustainable Agriculture: Definitions and Terms. Special Reference Briefs Series no. SRB 99-02. ISSN 1052-5368.
- Gorlach, J., Volrath, S., Knauf-Beiter, G., Hengy, G., Beckhove, U., Kogel, K.H., Oostendorp, M., Staub, T., Ward, E., Kessmann, H. and Ryals, J. (1996). Benzothiadiazole, a novel class of inducers of systemic acquired resistance, activates gene expression and disease resistance in wheat. Plant cell. 8: (4): pp. 629-643. <http://www.plantcell.org/cgi/content/abstract/8/4/629>.
- Gorlach, J., Volrath, S., Knauf-Belter, G., Hengy, G., Beckhove, U., Kogel, K.H., Oostendorp, M., Staub, T., Ward, E., Kessmann, H. and Ryals, J. (1996). Benzothiadiazole, a novel class of inducers of systemic acquired resistance, activates gene expression and disease resistance in wheat. Plant Cell. 8.

- Gozzo, F. (2004). Systemic acquired resistance in crop protection. Outlook on pest management. DOI: 10.1564/15feb10. <http://www.researchinformation.co.uk/pest/sample/15-1/11-Gozzo.pdf>
- Graziano, M. and Lamattina, L. (2005). Nitric oxide and iron in plants: an emerging and converging story: *TRENDS in Plant Science*. 10 (1), Available online at <http://www.sciencedirect.com>.
- Grigg, D.B. (1993). *The World Food Problem*. 2nd edition. Published by Blackwell Publishing Press. ISBN: 0631176330.
- Grimm, H. and Calder, P.C. (2002). Immunonutrition. *CABI Publishing Press, British Journal of Nutrition*. 87: S1.
- Gueye, E.F. (1998). Village egg and fowl meat production in Africa. *World's Poultry Science Journal*. 54: pp. 73-86.
- Gunter, L.F. and Centner, T.J. (2000). Characteristics of state agricultural pesticide collection programs. *Journal of Environmental Management*. 58: 61.
- Hamm, U. and Gronefeld, F. (2004). *The European Market for Organic Food: Revised and Updated Analysis. Organic Marketing Initiatives and Rural Development*, School of Management and Business, University of Wales Aberystwyth, United Kingdom. 5.
- Hamm, U., Gronefeld, F. and Halpin, D. (2002). *Analysis of the European Market for Organic Food. Organic Marketing Initiatives and Rural Development 1*. School of Management and Business, University of Wales, Aberystwyth, UK.
- Hanson, P., Chen, J.T., Kuo, C.G., Morris, R. and Opena, R.T. (2001). *Tomato Production*. Prepared by T. Kalb. Published by AVRDC. Assessed on the 27th July 2006 at: <http://www.avrdc.org/LC/tomato/production/01title.html>.
- Harris, C.R. (1969). Insecticide pollution and soil organisms. *Proc. Entomol. Soc. Ont.* 100: pp. 14-29.
- Hawkins, B.A. and Cornell, H.V. (2000). *Theoretical Approaches to Biological Control*, edited by Cambridge University Press, <http://www.else.hebis.de/pdflinks/06011614022528437.pdf> (accessed on February 16th 2006).
- Hayashi, S., Ganno, K., Ishii, Y. and Tanaka, I. (2002). *Robotic Harvesting System for Eggplants*. Published by Japanese International Research Centre for Agricultural Sciences. 39(3).
- Herdtt, R.W. and Steiner, R.A. (1995). Agricultural sustainability, concepts and conundrums. In: Vic Barnett, Rodger Payne and Roy Steiner, eds. *Agricultural Sustainability, Economic, Environmental and Statistical Considerations*, Teachester, New York, Brisbane, Toronto, Singapore. John Wiley, S. 3-13.
- Hermansen, J.E. and Horsted, K. (2004). *Organic poultry farming*. Paper presented at 1st international congress on Organic Animal Production and Food Safety, Kusadasi—Türkiye, 28 April–1 May 2004; Published in Incoglu, Serife, eds. *Tebliğler*, Izmir Regional Chamber of Veterinary Medicine. pp. 271-284.
- Hickey, S. (2005). Understanding the politics of challenging chronic poverty: some conceptual approaches. Presentation at Policy Influence and Media Engagement, a joint ODI-CPRC workshop, at ODI on 17-18 January 2005.

- Hiernaux, P. (1983). Les ressources végétales et leur productivité. In: Wilson, R.T., de Leeuw, P.N., De Haan, C. eds. *Recherches sur les systèmes des zones arides du Mali: résultats préliminaires*. Research Report No. 5. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.
- Hill, S.B. (1972). Effects of agriculture on soil mites. Unpublished paper presented to joint meeting of Entomol. Soc. Am., Entomol. Soc. Que., and Entomol. Soc. Can., Montreal, 26th November 1972.
- Hill, S.B., Metz, L.J. and Farrier, M.H. (1975). Soil mesofauna and silvicultural practices. In: Bernier, B. and Winget, C.H. eds. *Forest Soils and Forest Land Management*. Pr. Univ. Laval, Quebec. pp. 119-135.
- Hinrichs, C.C. and Welsh, R. (2003) The effects of the industrialization of US livestock agriculture on promoting sustainable production practices. Kluwer Academic, The Netherlands.
- Hochmuth, G. J., Maynard, D. N., Vavrina, C. S., Stall, W. M., Kucharek, T.A., Stansly, P.A., Smith, T.S.A., and Smajstrla, A.G. (1999). Tomato Production in Florida. Published online by the University of Florida. Accessed on the 26th January, 2007 at: <http://www.uog.edu/cals/PEOPLE/PUBS/Tomatoes/CV13700.pdf>
- Hocombe, S.D. (1968). Herbicides in soil. In: Fryer, J.D and Evans, S.A. eds. *Weed Control Handbook*. Blackwell, Oxford. 1: pp. 152-158.
- Hoitink, H.A.J. and Fahy, P.C. (1986). Basis for the control of soil-borne plant pathogens with compost. *Annual Review of Phytopathology*. 24: pp. 93-144.
- Houot, S., Chaussod, R. (1995). Impact of agricultural practices on the size and activity of the soil microbial biomass in a long-term field experiment. *Biology and Fertility of Soils*. 19.
- Hovi, M., Sundrum, A., and Baars, T., eds. (2001b). Feeding for Health and Welfare. Proceedings of the 4th NAHWOA-Workshop, 24-27.03.2001, Wageningen, NL, NAHWOA—Network of Animal Health and Welfare in Organic Agriculture. 198-202.
- Hovi, M., Sundrum, A., Hovi, M. and Baars, T., eds. (2001a). Network of Animal Health and Welfare in Organic Agriculture. Wageningen, NL <http://www.orgprints.org/00000953>.
- Huber, H.U. (1987). Untersuchungen zum Einfluss von Tages- und Kunstlicht auf das Verhalten von Hühnern. Ph.D. Thesis, ETH Zürich. In: Zeltner, E., Hirt, H. and Hauser, J. eds *How to Motivate Laying Hens to Use the Hen Run*. Proceedings of the 2nd SAFO Workshop, Witzenhausen, Germany.
- Huber-Eicher, B. and Wechsler B. (1998). The effect of foraging material and perch height on feather pecking and feather damage in laying hens. *Applied Animal Behaviour Science*. 58: pp. 131-141.
- Huber-Eicher, B. and Wechsler, B. (1997). Feather pecking domestic chicks: Its relation to dustbathing and foraging. *Animal Behaviour*. 54: pp. 757-767.
- Hughes, B.O. and Duncan, I.J.H. (1972). The influence of strain and environmental factors upon feather pecking and cannibalism in fowls. *British Poultry Science*, 13.

- Idris, A.B. and Grafius, E. (1995). Wildflowers as nectar sources for *Diadegma insulare* (Hymenoptera: Ichneumonidae), parasitoid of diamondback moth (Lepidoptera: Yponomeutidae). *Environmental Entomology*. 24: pp. 1726-1735.
- IFOAM (2000). Basic Standard for Organic Production and Processing. Decided by the IFOAM General Assembly in Basel, Switzerland, September 2000, Tholey-Theley. Available at: http://www.ifoam.org/standard/index_neu.html.
- IIED (1997). Changing Consumption and Production Patterns: Unlocking Trade Opportunities. (International Institute for Environment and Development). In: Nick Robins and Sarah Roberts eds. United Nations Department of Policy Coordination and Sustainable Development, United Nations, New York, USA.
- ILCA (1979b). Trypanotolerant livestock in West and Central Africa Vol. 2: Country Studies. International Livestock Centre for Africa (ILCA) Mono. No 2. Addis Ababa, Ethiopia, ILCA.
- ILCA/FAO/UNEP (1979). Trypanotolerant livestock in West and Central Africa. Volume 1: General Study, Volume 2: Country Studies. ILCA Monograph 2, CA, Addis Ababa, Ethiopia.
- Ingham, R. (1993). Report to the Oregon Potato Commission, Dept. of Botany and Plant Pathology, Oregon State Univ., Corvallis, OR.
- Ivey P.W. and Johnson S.J. (1998). Integrating control tactics for managing cabbage looper (Lepidoptera: Noctuidae) and diamondback moth (Lepidoptera: Yponomeutidae) on cabbage. *Tropical Agriculture*. 75: pp. 369-374.
- Jensen, U.B., Elmholt, S. and Labouriau, R. (2000). Distribution of Ergosterol in organically and conventionally cultivated agricultural soils. *Biological Agriculture and Horticulture*. 18: pp. 113-125.
- Jersey, R.I.M. (1992). U.K. Resource Inventory and Management: Nigerian livestock resources. 1-4.
- Jeune Afrique. (1973). The atlas of Africa. In: J.E.O. Rege, G.S. Aboagye and C.L. Tawah eds. Shorthorn Cattle of West and Central Africa IV. Production Characteristics. Published by FAO, Rome.
- Joergensen, R.G. (1995). The fumigation extraction method. In: Alef, K. and Nannipieri, P. eds. *Methods in Applied Soil Microbiology and Biochemistry*. Academic Press, London.
- Joergensen, R.G. (1996a). The fumigation-extraction method to estimate soil microbial biomass: calibration of the *k*EC factor. *Soil Biol Biochem*. 28: 25-31.
- Joergensen, R.G. and Mueller, T. (1996). The fumigation-extraction method to estimate soil microbial biomass: calibration of the *k*EN value. *Soil Biol. Biochem*. 28: pp. 33-37.
- Jones, L.H.P. and Jarvis, S.C. (1981). The fate of heavy metals. In: D.J. Greenland and M.H.B. Hayes, eds. *The Chemistry of Soil Processes*, Chichester, New York, USA.
- July, R. (1975). Pre-Colonial Africa. In: Kajoba, G.M. *Land Use and Land Tenure in Africa: towards an evolutionary conceptual framework*. Assessed on the 4th August 2006 at: <http://www.codesria.org/Links/conferences/ifs/Kajoba.pdf>.

- Kappen, L., Friedmann, E. I. and Giarty, J. (1981). Ecophysiology of lichens in the dry valleys of southern Victoria Land, Antarctica. In: Hall and Otte, (Ed.). *Biological Weathering on Nunataks of the Juneau Icefield, Alaska. Microclimate of the cryptoendolithic lichen habitat.* Flora, 171, pp. 216-235.
- Karaban, R. and Kuc', J. (1999). Induced resistance against pathogens and herbivores: an overview. In: Agrawal, A.A., Tuzun, S. and Bent, E. eds. *Induced Plant Defences Against Pathogens and Herbivores; Biochemistry, Ecology, and Agriculture.* The American Phytopathological Society Press, St. Paul., USA.
- Kawerau, J.G. (2005). *Aubergine Eggplant Cultivation and Growing.* Accessed on the 11th July 2006 on: <http://www.turkishlanguage.co.uk/aub.htm>.
- Kennedy, G.G. and Storer, N.P. (2000). Life systems of polyphagous arthropod pest in temporally unstable cropping systems. *Annual Review of Entomology.* 45: pp. 467-493.
- Kent, R., Johnson, D.E. and Becker, M. (2001). The influences of cropping system on weed communities of rice in Côte d'Ivoire, West Africa: Agriculture, Ecosystems and Environment. 87.
- Khan, M.U., Qasim, M., Jamil, M. and Pakistan, I.K. (2002). Effect of Different Levels of Zinc on the Extractable Zinc Content of Soil and Chemical Composition of Rice, Faculty of Agriculture, Gomal University, Pakistan.
- Kim, C.K. and Curry, J. (1993). Faradism, flexible specialization and agricultural industrial restructuring: The case of the US broiler industry. *Sociologia Ruralis* 33(1): pp. 61.
- King, E.G., Hopper, K.R. and Powell, J.E. (1985). Analysis of systems for biological control of crop arthropod pests in the U.S. by augmentation of predators and parasites. In: Hoy, M.A. and Herzog, D.C. eds. *Biological Control in Agricultural IPM Systems.* Academic Press, London. pp. 201-227.
- Klassing, K.C. (1998). Nutritional modulation of resistance to infectious diseases. *Poultry Science.* 77.
- Koning, R.E. (1994). Flower Structure. Plant Physiology Information Website. http://www.plantphys.info/plants_human/flowerstructure.html.
- Köpke, U. (1999). Review of crop production and weed control: state of the arts and outlook. In: Isart, J. and Llerena, J.J., eds. *Organic Farming Research in the EU, Towards 21st Century.* ENOF White Book. European Network for Scientific Research Co-ordination in Organic Farming (ENOF), Barcelona.
- Kortbech-Olesen, R. (2001). World Markets for Organic Fruit and Vegetables: opportunities for developing countries in the production and export of organic horticultural products. FAO, Rome.
- Kortbech-Olesen, R. (2002). Market opportunities for organic products in Europe and North America. United Nations Conference on Trade and Development, Italy 2002. Accessed on the 11th July 2006. (<http://www.intracen.org/mds/sectors/organic/sana.htm>).
- Kotschi, J. (1985). Möglichkeiten für eine ökologische Agrarproduktion in der Dritten Welt. In: Vogtmann, H. ed. *Oekologischer Landbau – Landwirtschaft mit Zukunft.* Stuttgart.

- Kotschi, J. ed. (1986). Control of desertification in African drylands: problems, experiences, guidelines. Sonderpublikation der GTZ 168, published jointly by the Commission of the European Communities (CEC) and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) Eschborn 1986.
- Kristiansen, P.E. (2003). Sustainable Weed Management in Organic Herb and Vegetable Production: PhD thesis, University of New England. Deposited in organic eprints. Can be accessed at: <http://www.orgprints.org/4829/01/4829.pdf>.
- Krul, J.M., Penning de Vries, F.W.T. and Traoré, F. (1982). Le processus du bilan d'azote. In: Penning de Vries, F.W.T., Djitéye, M.A. (eds.), La productivité des pâturages sahéliens. Une étude des sols, des végétations et de l'exploitation de cette ressource naturelle. Pudoc, Wageningen, The Netherlands.
- Kuepper, G. and Born, H. (1999). Organic Tomato Production. NCAT Agriculture Specialists. Online publication by ATTRA-National Sustainable Agriculture Information Service. <http://www.attra.org/attra-pub/tomato.html#r4>.
- Kürklü, A. (1990). Greenhouse heating systems and comparison with the ones used in greenhouses in Antalya. MSc Thesis, University of Çukurova, Adana, Turkey, p. 74.
- Kürklü, A. (1995). Effects of Temperature and Time of Harvest on the Growth and Yield of Aubergine (*Solanum melongena* L.). Tr. J. of Agriculture and Forestry. 22.
- Ladd, J.N., Amato, M., Zhou, L.K. and Schultz J.E. (1994). Differential effects of rotation, plant residue and nitrogen fertilizer on microbial biomass and organic matter in an Australian Alfisol. Soil Biology and Biochemistry. 26: 821-831.
- Lampkin, N. (1997). Organic Poultry Production. Welsh Institute of Rural Studies. The University of Wales, Aberystwyth, UK.
- Landis, D.A., Wratten S.D. and Gurr, G.M. (2000). Habitat management to conserve natural enemies of arthropod pests in agriculture. Annual Review of Entomology. 45: 175-201.
- Lardner, K.S. (2004). Doing things right-Bird Welfare. University of Saskatchewan. Accessed on the 17th July 2006 at: <http://www.poultryworkshop.com/Presentations/Karen%20Schwean%20Lardner/Bird%20Welfare.pdf>.
- Lawton, K., Friedrich, L., Hunt, M., Weymann K., Delaney, T., Kessmann, H., Staub, T. and Ryals, J. (1996). Benzothiadiazole induces disease resistance in Arabidopsis by activation of the systemic acquired resistance signal transduction pathway. Plant J. 10.
- Lee, L-W. and Shin, J-H.(1998). Optimal Irrigation Management System of Greenhouse Tomato based on Stem Diameter and Transpiration Monitoring. Available at: <http://www.jsai.or.jp/afita/afita-conf/1998/P29.pdf>
- Leeson, S. (2001). Feeding Programmes for Laying Hens. Published American Soybean Association Bulletin. PO49. Available at: <http://www.asaea.com/graphics/pdfs/PO49-Leeson.pdf>.
- Lim, G.S. (1986). Biological control of diamondback moth. In: Talekar, N.S. and Griggs, T.D. eds. Diamondback Moth Management. Proceedings 1st International Workshop, Shanhua, Taiwan. Asian Vegetable Research and Development Center. pp. 159-171.

- Liu, S., Carlson, G.A. and Hoag, D.L. (1995). Trade-off analysis of herbicide withdrawals on agricultural production and groundwater quality. *Journal of Agricultural and Applied Economics*. 27: 283.
- Livingstone, D.A. (1975). Late Quaternary Climatic Change in Africa: Department of Zoology, Duke University, Durham, North Carolina 27706.
- Lockeretz, W. and Lund, V. (2003). Socio-economic aspects of animal health and food safety in organic farming. *Proceedings of the 1st SAFO Workshop*, 5-7 September 2003, Florence, Italy. pp. 201-210. Online publication by the organic eprints.
- Loomis, R.S. and Connor, D.J. (1992). *Crop Ecology: Productivity and Management in Agricultural Systems*. Cambridge Univ. Press, Cambridge, UK.
- Lopez-Bote, C.J., Sanz, A.R., Castaño, A., Isabel, B. and Thos, J. (1998). Effect of free-range feeding on *n*-3 fatty acid and α -tocopherol content and oxidative stability of eggs. In: Zeltner, E., Hirt, H. and Hauser, J. *How to motivate laying hens to use the hen run*. *Proceedings of the 2nd SAFO Workshop*, Witzenhausen, Germany. *Animal Feed Science and Technology* 72: pp. 33-40.
- Lvins, A. (1976). Exploring energy-efficient futures for Canada. *Conservation Notes*. 1 (4): pp. 5-16.
- Lynam and Herdt (1989). Concepts and Issues of Sustainability in Countries in Transition – An Institutional Concept of Sustainability as a Basis for the Network (quoted by Lutteken, A. and Hagedorn, K). Humboldt University of Berlin, Germany
- Lyon, G.D. and Newton, A.C. (2005). Induced plant disease resistance. Available at: <http://www.scri.sari.ac.uk/SCRI/web/site/home/ResearchAreas/TopicsinPlantPathology/ResistanceElicitors/elicitors.asp> accessed on 10.06.2005.
- M.H.B., eds. *The Chemistry of Soil Processes*. Chichester, New York.
- Mäder, P., Edenhofer, S., Boller, T., Wiemken, A. and Niggli, U. (2000). Arbuscular mycorrhizae in a long-term field trial comparing low-input (organic, biological) and high-input (conventional) farming systems in a crop rotation. *Biol. Fertil. Soils*. 31: 150-156.
- Mangan, F.X., Herbert, S.J. and Litchfield, G.L. (1991). Cover crop management systems for broccoli. In: W.L. Hargrove, ed. *Cover Crops for Clean Water, Soil and Water Conservation Society*, Ankeny, IA. 178-179.
- Maqsood, M., Irshad, M., Wajid, S.A. and Hussain, A. (1999). Growth and yield response of Basmati-385 to ZnSO application. *Pak. J. Bio. Sci.*, 2.
- Marsh, J.S. (1997). The policy approach to sustainable farming systems in the EU: Centre for Agricultural Strategy, The University of Reading, Reading, UK.
- Martin, J.H. et al. (1994). Testing the iron hypothesis in ecosystems of the equatorial Pacific Ocean. *Nature*. 371.
- Martinez, G.M. and Banados, F. (2004). Impact of EU organic product certification legislation on Chile organic exports: Department of Agricultural Sciences, Centre for Food Chain Research, Imperial College London, Wye, Ashford, Kent TN25 5AH, UK, *Food Policy*. 29.

- Matthews, B. (2003). USDA ARS, SGIL. http://www.bldg6.arsusda.gov/benlab/Soybean%20Defense%20Response/oxidative_burst1.htm accessed on 14.06.2005.
- Maule, J.P. (1990). The cattle of the tropics. Centre for Tropical Vet. Med., University of Edinburgh, Edinburgh, UK.
- May, R.M. (1977). Food lost to pests. In: Hill S.B., ed. Agricultural Chemicals and the Soil. Ecological Agriculture Project, Nature. 267 (5613): 669-670.
- McCauley, A., Jones, C. and Jacobson, J. (2003). Soil pH and organic matter. Sourced from www.agronomy.org/cca/exam_pdf/ss01260.pdf (on 12/03/04).
- Medawar, P. (1969). Induction and Intuition in Scientific Thought. Methuen, Lond. 62.
- Medina, E. and Cuevas, E. (1989). Patterns of nutrient accumulation and release in Amazonian forests of the upper Rio Negro Basin. In: Matson, P.A., McDowell, W.H., Townsend, A.R. and Vitousek, P.M. eds. The globalization of N deposition: ecosystem consequences in tropical environments. Kluwer Academic Publishers, Netherlands. Biogeochemistry 46.
- Melander, B. (1998). Economic aspects of physical intra-row weed control in seeded onions. In: Foguelman, D. and Lockeretz, W., eds. Organic Agriculture—the Credible Solution for the 21st Century: Proceedings of the 12th International IFOAM Scientific Conference. International Federation of Organic Agriculture Movements, Mar del Plata, Argentina.
- Melander, B. (1998). Interactions between soil cultivation in darkness, flaming and brush weeding when used for in-row weed control in vegetables. Biological Agriculture and Horticulture. 16 (1): 1-14.
- Mellor, E. (1922). Vitricolous lichens and the deterioration of church windows. In Hall and Otte (Ed), Biological Weathering on Nunataks of the Juneau Icefield, Alaska. Permafrost and Periglacial Processes, Vol 1: p 190
- Michelson, J., Hamm, U., Wynen, E. and Roth, E. (1999). The European market for organic products: growth and development. Organic farming in Europe: Universitat Hohenheim, Germany. Economics and Policy. 7.
- Mkize, N. and Villet, N.H. (2001). Seasonal rates of parasitism of diamondback moth (*Plutella xylostella*) in subsistence cabbage crops in the Eastern Cape, South Africa. Department of Zoology and Entomology, Rhodes University, Grahamstown.
- Mohr, E.C.J., van Baren, F.A. and van Schuylenborgh, J. (1972). Tropical Soils: Comprehensive Study of Their Genesis. 3rd ed. 481.
- Montsma, G. (1960). Observations of milk yield and calf growth and conversion rate on three types of cattle in Ghana. Trop. Agric. (Trinidad). 37.
- Moore, N. (1967). A synopsis of the pesticide problem. Adv. Ecol. Res. 4: 75-129 .
- Moroney, M. (2003). Farm mechanisation strategies change more machine challenges. <http://www.farmersjournal.ie/indsup2003/machinery.pdf>.
- Moroney, M. (2003). Farm mechanisation strategies change more machine challenges: Agriculture New challenges, new opportunities, Reland.

- Mostaghimi, S., McClellan, P.W. and Cooke, R.A. (1993), Pesticide contamination of groundwater in Virginia: BMP impact assessment. *Water Science Technology*. 28: 79.
- Mueller-Harvey, I., Juo, A.S.R. and Wild, A. (1985). Soil organic carbon, nitrogen, sulphur and phosphorus after forest clearance in Nigeria: mineralization rates and spatial variability. *Journal of Soil Science* 36(4). ISSN: 0022-4588.
- Murwira, K.H., Swift, M.J. and Frost, P.G.H. (1995). Manure as a key resource in sustainable agriculture. In: Powell, J.M., Fernandez-Rivera, S., Williams, T.O. and Renard, C. eds. *Livestock and Sustainable Nutrient Cycling*. 211-226.
- Narendra, P.S., Reitbergen, S., Heimo, R.C. and Patel, J. (1994). A Strategy for the Forest Sector in Sub-Saharan Africa. Technical Paper No. 251. Africa Technical Department Series, Washington, D.C. World Bank.
- Naylor, R.L. (1996). Energy and resource constraints on intensive agricultural production: *Annu. Rev. Energy Environment*. 21.
- Naylor, R.L. and Ehrlich, P.R. (1997). The value of natural pest control services in agriculture. In: Daily, G. ed. *The Value of Ecosystem Services*, Island. New York.
- Needham, J. (1932). Thoughts on the problem of biological organization. *Scientia* (Milan). 52: 84-92.
- Ngere, L.O. (1974). Crossbreeding for beef in Ghana and Nigeria. In: *Proc. First World Congress on Genetics and Applied Livestock Production*, Madrid, Spain.
- Ngere, L.O., Hagan, R., Oppong, E.N.W. and Lossli, J.K. (1975). Milking potential of the West African Shorthorn cow. *J. Agric. Sci. (Ghana)* 8: 31-35.
- Nilsson, U., Lundqvist, P. and Martensson, L. (2000). Organic farming and working conditions. In: Alföldi, T., Lockeretz, W. and Niggli, U., eds. *IFOAM 2000—The World Grows Organic. Proceedings of the 13th International IFOAM Scientific Conference*. Convention Centre Basel, Switzerland 28 to 31 August 2000. pdf Hochschulverlag AG an der ETH Zurich, Basel.
- Oberson, A., Oehl, F., Langmeier, M., Fliessbach, A., Dubois, D., Mäder, P., Besson, J.M. and Frossard, E. (2000). Can increased microbial activity help to sustain phosphorous availability? In: Alföldi, T., Lockeretz, W. and Niggli, U. eds. *Proceedings of 13th International IFOAM Scientific Conference*. pdf Hochschulverlag, Zürich. 27.
- Olutogun, S. (1976). Reproductive performance and growth of N'Dama and Keteku cattle under ranching conditions in the Guinea savanna of Nigeria. *Dept. Anim. Sci., Univ. of Ibadan, Nigeria*. (Ph.D. thesis).
- Omay, A.B., Rice C., W., Maddox L.D. and Gordon W.B. (1997). Changes in soil microbial and chemical properties under long term crop rotation and fertilisation. *Soil Sci. Soc. Am. J.*, 61: 1672-1678.
- Palm, C.A., Gachengo, C.N., Delve, R.J., Cadisch G. and Giller, K.E. (2001). Organic inputs for soil fertility management in tropical agroecosystems: application of an organic resource database. *Agriculture, Ecosystems and Environment*. 83.
- Palmer, R. J. (1989). Microbial weathering of building stone. *Abstracts; Biological Conference, Moscow*, 132

- Parella, M.P., Heinz, K.M. and Nunney, L. (1992). Biological control through augmentative releases of natural enemies: a strategy whose time has come. *American Entomologist*. 38.
- Patriquin, D.G., Blaikie, H., Patriquin, M.J. and Yang C. (1993). Farm measurements of pH, electrical conductivity and nitrate in soil extracts for monitoring coupling and decoupling of nutrient cycles. *Biological Agriculture and Horticulture*. 9: 231-272.
- Pearce, D.W., Atkinson, G.D. and Dubourg, W.R. (1994). *The Economics of Sustainable Development: Centre for Social and Economic Research on the Global Environment (CSERGE)*, University College, London, Gower Street, London WC1E 6BT, UK.
- Pierce, J.T. (1990). *The Food Ressource*, Longman Publishing, New York.
- Pieterse, C.M.J., van Wees, S.C.M., Johan A. van Pelt, J.A., Marga Knoester, M., Laan, R., Gerrits, H., Weisbeek, P.J. and van Loon L.C., (1998). A novel signaling pathway controlling induced systemic resistance in *Arabidopsis*. *Plant Cell*. 10: 1571-1580.
- Pimentel, D. and Greiner, A. (1997). Environmental and socioeconomic costs of pesticide use. In: Pimentel, D. ed. *Techniques for Reducing Pesticide Use: Economic and Environmental Benefits*. John Wiley and Sons, Chichester. 51-78.
- Pimentel, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., Nelson, J., Lipner, V., Giordano, S., Horowitz, A. and D'Amore, M. (1992). Environmental and human costs of pesticide use. *Bioscience*. 42: 750-760.
- Plucknett, D.L. (1994). Sources of the next century's new technology. In: Anderson, J.R. ed. *Agricultural Technology: Policy Issues for the International Community*. CAB Int. Wallingford, UK.
- Plunknett, D.L. (1995). Prospects of meeting future food needs through new technology. In: Naylor, R.L. (1996). *Energy and Resource Constraints on Intensive Agricultural Production*. *Annual Review of Energy and the Environment*. 21.
- Porter, P.M., Huggins, D.R., Perillo, C.A., Quiring, S.R. and Crookston, R.K. (2003). Organic and other management strategies with two- and four-year crop rotations in Minnesota. *Agronomy Journal*. 95(2).
- Powell, J.M. and Williams, T.O. (1993). Livestock, nutrient cycling and sustainable agriculture in the West African Sahel. *Gatekeeper Series SA37*. International Institute for Environment and Development (IIED), London. 15.
- Powell, W., (1986). Enhancing parasitoid activity in crops. In: Waage, J., Greathead, D. (Eds.), *Proceedings of the 13th Symposium of the Royal Entomological Society of London on Insect Parasitoids*. Academic Press, London. Pp. 319-339.
- Pritchard, J.M. (1979). *Africa: A Study Geography for Advanced Students*. Longman Group, Revised 3rd. edn, UK.
- Rao, N. (2003). *Economic Efficiency and Farm Mechanisation: New Delhi*, Serials Pub.ISBN 81-86771-25-5.
- Redclift, M. (1987). *Sustainable Development: Exploring the Contradictions*. Published by Routledge, London: ISBN: 0415050855.

- Redclift, M. (1994). Reflections on the 'sustainable development' debate. *Int. J. Sustainable Dev. World Ecology*.
- Rees, R.M. (1989). Measurement of nitrogen mineralisation in soil incubations. In: Hansen, J.A. and Henriksen, K., eds. *Nitrogen in Organic Wastes Applied to Soils*. Academic Press, London. 11-24.
- Reganold, J., Elliott, L. and Unger, Y. (1987). Long-term effects of organic and conventional farming on soil erosion. *Nature*. 330: 370-372.
- Ridgway, R.L. and Vinson, S.B. (1977). *Biological Control by Augmentation of Natural Enemies*. Plenum Press, New York.
- Ritter, M. (2003). Factors Affecting Soil Development. http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/soil_systems/soil_development_soil_forming_factors.html - 15k.
- Ritter, W.F. (1990). Pesticide contamination of ground water in the United States: a review. *Journal of Environmental Science and Health*. 25.
- Robins, N., Roberts, S. and Abbot, J. (2000). *Who Benefits? A Social Assessment of Environmentally Driven Trade*. IIED, London.
- Roland, D.A. Sr. (1988). Eggshell problems: Estimates of incidence and economic impact. *Poultry Science*. 67: 1801-1803.
- Romheld, V. and Marschner, H. (1991). Genotypical differences among Gramineae species in release of phytosiderophores and uptake of iron phytosiderophores. *J. Plant and Soil*. 123.
- Rosenzweig, C. and Liverman, D. (1992). Predicted effects of climate change on agriculture: A comparison of temperate and tropical regions. In: Majumdar, S.K. ed. *Global Climate Change: Implications, challenges, and mitigation measures*. The Pennsylvania Academy of Sciences. 342-61.
- Ross, D.J.K., Tate, R., Cairus, A., Mayricbt, K.F., and Pursic, E.A. (1982). Restoration of pasture after topsoil removal: effect of soil carbon and nitrogen mineralization, microbial biomass and enzyme activities. *Soil Biology & Biochemistry*. 14.
- Ross, S.D. (1944). Nigerian cattle types. In: Rege, J.E.O., Aboagye G.S. and Tawah, C.L., eds. *Shorthorn Cattle of West and Central Africa IV. Production Characteristics*. Farm Forest (Nigeria). FOA.
- Rothrock, C.S. and Kendig, S.R. (1991). Suppression of black root rot on cotton by winter legume cover crops. In: Hargrove, W.L. ed. *Cover crops for clean water*. Soil and Water Conservation Society, Ankeny, Iowa. 155-156.
- Rouse, J.E. (1970). *World Cattle. II: Cattle of Africa and Asia*. University of Oklahoma Press. Oklahoma City, OK, USA.
- Roy, R.N., Misra, R.V., Lesschen, J.P. and Smaling, E.M. (2003). Assessment of soil nutrient balance: FAO Land and Water Development, Division Rome, FAO Consultant, Wageningen University, The Netherland: FAO bulletin 14 (2003).
- Ruttan, V.W. (1992). Sustainable growth in agricultural production: into the 21st century, *Choices*. 7.
- Ryan, M. (1999). Is an enhanced soil biological community, relative to conventional neighbours, a consistent feature of alternative (organic or biodynamic) agricultural systems. *Biological Agriculture and Horticulture*. 17: 131-144.

- Sanders, D.C. (1999). North Carolina Commercial Vegetable Recommendations. North Carolina Cooperative Extension Service. Raleigh, NC. 5-8.
- Sanders, D.C. (2001). Fresh Market Tomato Production: Extension Horticultural Specialist Department of Horticultural Science College of Agriculture and Life Sciences North Carolina State University
- Sangakkara, U.R. (1998). Management of organic matter and nutrient turnover for increased sustainable tropical agricultural production and environmental preservation. Second Research Co-ordination Meeting of the FAO/IAEA Coordinated Research Project.
- Schlosser, E. (2001). Fast Food Nation. Houghton Mifflin. Boston.
- Schmidt, H.R. and Becker, S.J.A. (1999). The role of salicylic acid in disease resistance. In: Agrawal, A.A., Tuzun, A. and Bent, E., eds. Induced Plant Defences against Pathogens and Herbivores; Biochemistry, Ecology, and Agriculture. The American Phytopathological Society Press, St. Paul, MN, USA.
- Schonbeck, M.W. and Evanylo, G.K. (1998). Effects of mulches on soil properties and tomato production. I. Soil temperature, soil moisture and marketable yield. *Journal of Sustainable Agriculture*. 13(1): 55-81.
- Scialabba, N. (2000). Opportunities and constraints of organic agriculture. A socio-ecological analysis. FAO/World Agricultural Information Centre. Accessed on July 12th 2006 at: <http://www.fao.org/organicag/doc/SOCRATES1999.htm>.
- Scoones, I. and Toulmin, C. (1998). Soil nutrient balances: what use for policy? *Ag., Ecosys. Env.* 71: 255-267.
- Sequeira, L. (1983). Mechanism of induced resistance in plants. *Annual Review Microbiology*. 37: 51-79.
- Sharma, K. (2005). Induced plant disease resistance: An alternative method of controlling plant diseases. Working paper, Department of Plant Protection, University of Kassel, Witzenhausen (unpublished article).
- Shelton, A.M., Perez, C.J., Tang, J.D. and Vandenberg, J.D. (1996). Prospects for novel approaches towards management of the diamondback moth. In: Sivapragasam, A., Loke, W.H., Husson, A.K. and Lim, G.S. eds. The management of diamondback moth and other crucifer pests. Proceedings 3rd International Workshop. Malaysian Agricultural Research and Development Institute, Kuala Lumpur, Malaysia. 17-19.
- Shumway, C.R. and Chesser, R.R. (1994). Pesticide tax, cropping patterns, and water quality in south central Texas. *Journal of Agricultural and Applied Economics*. 26: 224.
- Sikora, L.J. and Yakovchenko, V. (1996). Soil organic matter mineralization after compost amendment. *Soil Science Society of America journal*.
- Sivapalan, A., Morgan, W.C. and Franz, P.R. (1993). Monitoring populations of soil microorganisms during a conversion from a conventional to an organic system of vegetable growing. *Biological Agriculture and Horticulture*. 10: 9-27.
- Skinner, E.P. (1964). The Mossi of Upper Volta: The Political Development of a Sudanese People. Stanford University Press.

- Skinner, J.A., Lewis, K.A., Bardon, K.S., Tucker, P., Catt, J.A. and Chambers, B.J. (1997). An overview of the environmental impact of agriculture in the UK. *Journal of Environmental Management*. 50.
- Smil, V. (1994). How many people can the earth feed? *Population Development, Rev.* 20.
- Smith, J.L., Papendick, R.I., Bezdicek, D.F. and Lynch, J.M. (1993). Soil organic matter dynamics and crop residue management. In: Metting, B. ed. *Soil Microbial Ecology*, Marcel Dekker, New York.
- Smith, L.C. (1998). Can FAO measure of Chronic Undernourishment be Strengthened? Food Consumption and Nutrition Division. FCND Discussion paper No. 44.
- Smith, S. and Read, D. (1997). *Mycorrhizal Symbiosis*. 2nd edn., London. Soil Science Department, North Carolina State University.
- Sparling, G.P., Ord, B.G. and Vaughan, D. (1981). Microbial biomass and activity in soils amended with glucose. *Soil Biology & Biochemistry*. 16.
- Stanford, G. and Smith, S.J. (1972). Nitrogen mineralisation potentials of soils. *Soil Sci. Soc. Amer. Proc.* sourced in March 2005 from <http://www.iaca.org/programmes/nafa/d1/crp/isotope-crp-second.pdf>. 36: 465-72.
- Staswick, P.E. and Lehman, C.C. (1999). Jasmonic acid signalled responses in plant. In: Agrawal, A.A., Tuzun, S. and Bent, E. eds. *Induced Plant Defenses against Pathogens and Herbivores; Biochemistry, Ecology, and Agriculture*. The American Phytopathological Society Press. 117-131.
- Stevenson, F.J. (1986). *Cycles of Soil*. Wiley J. and Sons. New York. 380.
- Stinner, R.E. (1977). Efficacy of inundative releases. *Annual Review of Entomology*. 22.
- Stolze, M., Piörr, A., Häring, A. and Dabbert, S. (2000). The environmental impacts of organic farming in Europe. *Organic farming in Europe*, University of Stuttgart-Hohenheim, Germany. 6.
- Stonehouse, D.P., Weise, S.F., Sheardown, T., Gill, R.S. and Swanton, C.J. (1996). A case study approach to comparing weed management strategies under alternative farming systems in Ontario. *Canadian Journal of Agricultural Economics*. 44(1): 81-99.
- Stoorvogel, J.J. and Smaling, E.M.A. (1994). Assessment of soil nutrient depletion in sub-Saharan Africa: 1983-2000. Main Report. DLO-Winand Staring Centre, Wageningen. The Netherlands. 1: 137.
- Suchner, U., Kuhn, K.S. and Furst, P. (2000). Clinical Nutrition and Metabolism Group Symposium on Nutrition in the severely-injured patient. *Proceedings of the Nutrition Society* (2000). 59: 553-563.
- Sullivan, P. (2003). Overview of Cover Crops and Green Manures—Fundamentals of Sustainable Agriculture. ATTRA Publication with ref. No. #IP024.
- Sullivan, P.G., Parrish, D.J. and Luna, J.M. (1991). Cover crop contributions to N supply and water conservation in corn production. *Amer. J. Alternative Agriculture*. 6: 106-115.
- Tabler, G.T. (2005). *Broiler Production Management*. Department of Poultry Science, University of Arkansas, Fayetteville, Arkansas 72701, USA.

- Tadelle, D. (1996). Studies on village poultry production systems in the central Highlands of Ethiopia. MSc. Thesis, Swedish University of Agricultural Sciences.
- Talekar, N.S. (1996). Biological control of diamondback moth in Taiwan: a review. *Plant Protection Bulletin* 38: 167-189.
- Talekar, N.S. and Shelton, A.M. (1993). Biology, ecology and management of the diamondback moth. *Annual Review of Entomology*. 38: 275-301.
- Thaler, S. J. (1999). Jasmonic acid mediated interactions between plants, herbivores, parasitoids, and pathogens: A review of field experiments in tomato. In: Agrawal, A.A., Karban, R. and Colfer, G.R., eds. *How Leaf Domatia and Induced Plant Resistance Affect Herbivores, Natural Enemies and Plant Performance*. OIKOS 89: 70-80. Copenhagen 2000. 319-331.
- Thompson, L.M. (1975). Weather variability, climate change and food production. In: Rosenzweig, C. and Liverman, D., eds. *Predicted Effects of Climate Change on Agriculture: A Comparison of Temperate and Tropical Regions*.
- Thompson, L.M. (1975). Weather variability, climatic change and grain production. In: Rosenzweig, C. and D. Liverman, 1992. *Predicted Effects of Climate Change on Agriculture: A comparison of temperate and tropical regions*. In: *Global climate change: Implications, challenges, and mitigation measures*.
- Thornbury, W.D. (1969) *Weathering, Erosion, and Mass Movement*. Available at: http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/mass_movement_weathering/chemical_weathering.html.
- Thorup-Kristensen, K. (2002). Utilising Differences in Rooting Depth to Design Vegetable Crop Rotations with High Nitrogen Use Efficiency: Proceedings of the Workshop Eco. Fertilization Veg. Booiij R. and Neeteson J., eds. *Acta Hort.* 571, ISHS 2002.
- Tiessen, H., Salcedo, L. H. and Sampaio, E.V.S.B. (1992). Nutrient and soil organic matter dynamics under shifting cultivation in semi-arid northeastern Brazil. *Agriculture, Ecosystems and Environment*. 38(3).
- Tisdale, S.L., Nelson, W.L., Beaton, D.L. and Havlin, L.J. (1993). *Soil Fertility and Fertilizers*. 5th ed. Macmillan Pub. Company, New York, USA.
- Toor, R.K. and Savage, G.P. (2006). Effect of semi-drying on the antioxidant components of tomatoes: *Food Chemistry*. 94.
- Toulmin, C. and Propper, S. (2000). *Land Reform North and South*. Assessed July 5th 2006 (<http://www.caledonia.org.uk/land/n&s.htm>).
- Turenne, J.T. (2001) Factors of soil formation. <http://www.nesoil.com/plymouth/formation.html>.
- Twince, C. (1985). *A Guide to Poultry Management*. The Crowood Press Limited, Ramsbury, Marlborough, Wiltshire UK.
- Ulrich, H. and Friederike, G. (2004). *Analysis of the European Market for Organic Food 2004*. Published by School of Management and Business, Cledwyn Building, University of Wales, UK.
- USDA Forest Service (1999). *Propagation Techniques: Agriculture Handbook*. 674.
- Vaarst, M. and Hovi, M. (2004). Organic livestock production and food quality: a review of current status and future challenges. *Proceedings of the 2nd SAFO Workshop*, Witzenhausen, Germany. Online publication by the organic prints.

- Van Engelen, V. (1993). Global and national soils and terrain digital databases (SOTER). Procedures manual. ISRIC. Wageningen.
- Van Loon, L.C., Bakker, P.A.H.M. and Pieterse, C.M.J. (1998). Systemic resistance induced by rhizosphere bacteria. *Annual Review of Phytopathology*. 36: 453-483.
- Vance, E.D., Brookes, P.C. and Jenkinson, D.S. (1987). An extraction method for measuring soil microbial biomass C. *Soil Biol. Biochem.* 19: 703-707.
- Vavel, G.E. (1994). Rotation and nitrogen fertilisation effects on changes in soil carbon and nitrogen. *Agronomy Journal*. 86: 319-325.
- Viandes, M.H.R. (1999). History of organic farming. In: Stoll, G., ed. *The Role of Agriculture and Rural Development in Asia. Regional Overview: Asia and the International Context* Available at: <http://www.unescap.org/rural/doc/OA/Asia.PDF>.
- Vinten, A.J., Whitmore, A., Bloem, J., Howard, R. and Wright F. (2002). Factors affecting N mobilisation/mineralisation kinetics for cellulose-glucose and straw amended sandy soil. ISBN: 0178-2762. *Biol. Fertil. Soil*. 36: 190.
- Waterer, D. (2005). Carrots production. University of Saskatchewan – Plant Science Department: <http://www.agr.gov.sk.ca/docs/crops/horticulture/carrots01.asp> - 33k.
- Weetman, G. and Hill, S.B. (1973). General environmental and biological concerns in relation to forest fertilization. Pp. 19-35. Leaflet in *Forest Fertilization, Symposium Proceedings*. USDA. For. Serv. Gen. Tech. Rep. NE-3. Accessible at: http://www.fs.fed.us/ne/newtown_square/publications/technical_reports/pdfs/scanned/gtr3.pdf
- Weetman, G., Knoweles, R. and Hill, S.B. (1972). Effects of different forms of nitrogen fertilizer on nutrient uptake by Black spruce and its humus and humus mesofauna. *Pulp. Pap. Res. Inst. Can. Woodl. Rep.* 39.
- Went, F.W. and Sheps, L.O. (1969). Environmental factors in regulation of growth and development: ecological factors. In: F.C. Steward, ed. *Plant Physiology: A Treatise*. Academic Press, New York. (5A): 299-419.
- West, A.W., Grant, W.D. and Sparling, G.P. (1987). Use of ergosterol, diaminopimelic acid and glucosamine contents of soil to monitor changes in microbial populations. *Soil Biology and Biochemistry*. 19: 607-612.
- Whiteside, T. (1977). The pendulum and the toxic cloud. *The New Yorker*, July 25, 30-55.
- Whittaker, G., Lin, B. and Vasavada, U. (1995). Restricting pesticide use: the impact on profitability by farm size. *Journal of Agricultural and Applied Economics*. 27: 352-362.
- Wichern, F., Lobe, I., Amelung, W., Muller, T., Joergensen, R. G. and Buerkert, A. (2004). Changes in amino acid enantiomers and microbial performance in soils from subtropical mountain in Oman abandoned for different periods. *Biology and Fertility of Soils*. 39: 398-406.
- Wichern, F., Richter, C. and Joergensen, R. G. (2003). Soil fertility breakdown in a subtropical South African vertisol site used as a home garden. *Biology and Fertility of Soils*. 37: 288-294.

- Willer, H. and Yussefi, M. (2000). *Organic Agriculture Worldwide*. Stiftung Ökologie und Landbau, Bad Dürkheim, Germany.
- Williams, R.J.P. and Frausto da Silva, J.J.R. (2002). The Involvement of Molybdenum in Life, Inorganic Chemistry Laboratory, University of Oxford, Oxford, UK; and Department of Chemistry, Instituto Superior Técnico, Lisbon, Portugal.
- World Meteorological Organization. 1979. Proceedings of the World Climate Conference. WMO. Geneva. In: Rosenzweig, C. and D. Liverman. eds. Predicted effects of climate change on agriculture: A comparison of temperate and tropical regions. In: *Global climate change: Implications, challenges, and mitigation measures*.
- Wu, J., Joergensen, R.G., Pommerening, B., Chaussod, R. and Brookes, P.C. (1990). Measurement of soil microbial biomass-C by fumigation-extraction—an automated procedure. *Soil Biol. Biochem.* 22: 1167–1169.
- Wynen, E. (1992). Conversion to Organic Agriculture in Australia: Problems and Possibilities in the Cereal-Livestock Industry. National Association for Sustainable Agriculture, Sydney, Australia.
- Wynen, E. (1997). Research on biological farming methods in Europe: perspectives, status and requirements. In: Krell, R., ed. *Biological Farming Research in Europe*. Food and Agriculture Organization of the United Nations, Rome. 6-48.
- Yuanzhi Li, Guangfu Luo, Yining Fan and Yi Chen (2004). A novel route to the synthesis of nanosized metallic molybdenum at moderate temperature and its catalytic properties, *Materials Research Bulletin* 39: Available online at <http://www.sciencedirect.com>.
- Yudelman, M. (1964). *Africans on the Land*. Harvard University Press, Cambridge, USA.
- Zehnder, G.W., Yao, C., Murphy, J.F., Edward J., Sikora, E.J., Joseph, W., Kloepper, J.W., Schuster, D.J., and Polston, J.E. (1998). Microbe-induced resistance: A novel strategy for control of insect-transmitted diseases in vegetables. Accessed on April 10th 2006 at: <http://ipmworld.umn.edu/chapters/zehnder.htm>
- ZMP, Ökomarktförum (2001). Organic farming in Germany. In: <http://www.fao.org/DOCREP/004/Y1669E/y1669e09.htm#TopOfPage>
- Zoras, A.A., Dimitris, A.P. and Giannakis H.M.Z. (2002). Compost Quality and use from Sewage Sludge, Organic Fraction of Municipal Solid Waste and Natural Zeolite—Clinopilolite: Proceedings of the 10th International Conference of the RAMIRAN Network 2002—Published by FAO.

INTERNET SITES

- Economic Research Services, United States Department of Agriculture (Organic Farming and Marketing), <http://www.ers.usda.gov/briefing/Organic/>
- Organic Consumers' Association, <http://organicconsumers.org/organic/survey072604.cfm>
- Seminars on Production and Export of Organic Fruits and Vegetables in Asia, Bangkok Thailand 3-5 November (2003), <ftp://ftp.fao.org/docrep/fao/006/ad429E/ad429E00.pdf>

World Market For Organic Fruits and Vegetables, Institute of Food and Agricultural Sciences, University of Florida, United States. <http://edis.ifas.ufl.edu/pdf/HS/HS21300.pdf>

The Role and Importance of Nitrogen in Your Soil. <http://www.cpit.ac.nz/subjects/horticulture/documents/nitrogen.pdf>.

Particle sizes—USDA and International Classification Systems. <http://www.krishniworld.com/html/soils3.html>.

Organic Fruits Production in Austria, <http://www.fao.org/DOCREP/004/Y1669E/y1669e05.htm#bm05>

European Commission Directorate-General for Agriculture, http://europa.eu.int/comm/agriculture/publi/fact/horti/2003_en.pdf

http://bldg6.arsusda.gov/benlab/Soybean%20Defense%20Response/salicylic_acid_synthesis.htm accessed on 14.06.2005.

United States Department of Agriculture, Natural Resources Conservation Services. (What is Soil?). Available at: <http://www.soils.usda.gov/education/facts/soil.html>.

Index

- A**
Aerobic N - mineralization 31, 32, 59, 60
Aesthetic forest use 18
Agricultural chemicals 71-75
—practices 7-10, 75
Allelochemicals 87
Amino acid requirements in broiler 159
Andropogon 190, 191
Anthracnose 137
Antimicrobial substances 91
Artificial Incubation 168
Attractants 84-87
Augmentative biological control 81
Avirulent pathogens 92
- B**
Battery Cage System 177, 178
Biological control 21, 37, 80-82, 94, 101
—weathering 35
Biomathematical modelling 179
Biotic factors 68
—stimuli 95
Bos taurus 188
Botrytis Leaf Blight 137
Brachiaria 190, 191
Broilers 165, 158-160, 181, 182, 184, 185
- C**
Calcium 35-37, 40, 47, 103, 106-109, 111, 136, 160-162, 164, 165, 195, 196
Cannibalism 174, 178, 187
Carbonation 35
Carrot Seedlings 127
—varieties - Nantes, Imperator, Chantenay, Danvers 128
Cattle 40, 187, 189, 190, 192-196
Certification bodies 3, 5, 51, 99
Chemical attractant 85, 87
—weathering 34-35
Chicken management 156, 158
Clay 36, 37, 42-45, 64, 110, 127
Climatic change on agricultural development 21, 67-68, 179, 180
—factors 40, 67-68, 179
Communal forests 19
Conservation 3, 7, 12, 14-18, 24, 47, 51, 80, 82, 107
Cover crops 1, 4, 40, 47-51, 53, 66, 81, 102, 104
Cultural practices 7, 9, 10, 75, 101, 120, 129, 131
- D**
Debeaking 187
Deep Litter System 177, 178
Demineralization 195
Desertification 36, 66
Dietary energy 158
—proteins 158
Downy Mildew 137

Dust bathing 179, 183

E

Edaphic factors 69

Education 7, 9, 10, 22, 28, 119, 144

Elicitor 89, 90, 93, 94, 97

Environmental changes 23, 180

—factors 37, 80, 131, 179

F

Factors affecting farmers 28

Farmers and community involvement 15

Feather plucking 178

Forest - Control of afforestation 17

—conservation and resources 16

—degradation 12

—development 15

—laws 14

—laws - reforming of 15

—laws - scope and policy 15

—protection 17

—sustainable management 17

—use - conservation 18

—zones in Africa 13

Forestry 11

Free Range System 172, 183

Freshwater swamps 13

Fundamental challenges to African Forests 12

Future Plan for Poultry Production 154

G

Gender equality and women development 8

Geographical information system (GIS) 179

Ghana Shorthorns 191, 192

Government's role and support institutions 17

Ground and surface water 40, 70

H

Harvesting 11, 18, 76, 116, 124, 126, 142

Housing of poultry 183

Human health 10, 72-74, 100, 101, 125

Humidity 12-13, 54, 67, 130, 138, 169, 170, 179-190

Hydrolysis 36

Hyparrhenia 190, 191

Hypersensitive responses 92

I

Igneous Rocks 37

Improving knowledge and technology of forest production 8

Induced resistance 88-89, 91-98

Inoculation 76, 92

Intensive management 154, 177

Iron 36, 37, 44, 103, 106, 110, 111, 154, 160, 164, 187, 196

Irrigation 129

J

Jasmonic acid 89, 91, 93, 96

K

Knowledge of propagation 120

L

Land right 32

—tenure 30

—use 31

Leasehold system 33

Leguminous residues 104

M

Magnesium 37, 40, 47, 103, 107, 108, 161-164, 195-196

Maintenance of site 76

Mangrove swamp 13

Marketing 5, 52, 123, 146, 149-151, 153, 154, 159, 173

Mechanization 115-119

Metamorphic rocks 37, 38

Microbial activities 50, 64

Mineralization 45, 47, 54-56, 105, 109, 112, 113

- Minerals 34–38, 40, 43, 44, 73, 78, 100, 109, 111, 159–162, 176, 195
- Mobile houses 184
- Molybdenum 103, 110–111, 196
- Muturu 192
- N - mineralization 34, 35, 53, 56, 57, 61–63, 113
- N**
- N'Dama cattle 188
- Neem 14, 79
- Nutrition 5, 9, 10, 90, 109, 110, 154, 157, 159, 161, 195
- requirements 157
- O**
- Oxidation 36
- P**
- Parasitism 81–82, 132–133
- Particles of soil 42
- Pathogen recognition 89
- Pathogenesis 90–95
- Pest control 37, 76, 80, 85, 137, 155, 166
- Pheromones 66, 84–86
- Phosphorus 46, 47, 50, 77, 78, 103, 104, 106, 107, 110, 113, 129, 140, 161, 162, 164, 165, 175, 196
- Physical weathering 34
- Phytoalexin 91
- Phytophthora Blight 142
- Plant nutrients 24, 43, 50, 103, 104
- Potassium 40, 46, 47, 78, 103, 107, 109, 129, 137, 161, 162, 164, 175, 182, 195, 196
- Poultry production 153–157, 172, 173, 175–177, 181, 183, 185
- Poverty and hunger 8, 20
- Practical poultry production 155
- Predators 39, 73, 79, 81–82, 84, 87, 171, 175, 178, 183–184
- Private forests 19
- sector involvement 16
- Productive forest use 18
- Prophylactic vaccination 179
- Protective forest use 18
- Purple blotch 136
- Pyrethrin 79
- R**
- Rainforest 13
- Remineralization 26, 112, 195
- Rhizobacteria 93, 95, 96
- Rhizobia bacteria 47, 104, 111
- Rocks 34–38, 74
- formation processes 36
- Role of investors in forest development 16
- Ryania 79, 80
- S**
- Sand 38, 40, 42–45, 54, 63–64, 66, 109, 112–113, 124, 127, 140, 183
- Savannah zone 13
- Sclerotinia 129–131
- Sedimentary rocks 37
- Seed propagation 121
- Selection of site 76
- Silt 43
- Sinusitis 185
- Skye's hybrids 177
- Soil acidity 55, 107, 108, 112
- air 45
- amendments 51, 52, 109
- and water conservation 47
- biological activities/ microorganisms 1, 54
- color 44
- composition 42
- conditions 44, 46, 47, 69, 76, 100, 104, 109, 129
- degradation 23, 24, 65, 66, 103
- density 44
- erosion 12, 38, 39, 49, 53, 65, 73
- formation 35, 39, 41
- management 31, 32, 39, 46, 47, 52, 60, 61, 65

—organisms 10, 34-35, 41, 48, 53-54, 72-74

—particles 42, 49, 51, 106, 107

—plasticity and cohesion 45

—pore spaces 44

—quality 8, 48, 50, 52, 55

—temperature 44

State forests 18

Stemphylium Leaf Blight 136

Sulphur 49, 103, 109, 113, 159, 195

Sustainable agriculture 7, 8, 22-24, 26, 27, 94

T

Textural classes 43

Tillage 40, 47-48, 51, 65, 69, 76, 101, 102, 107, 113, 129

Topography 34, 39-41

Trade in organic food 5

Transplanting 124, 141

U

Undernourishment 27

V

Vector control 179

Vegetative propagation 122

Ventilation 156, 169, 171, 174, 182, 183, 185

Verticillium Wilt 142

Vitamins 154, 158, 160, 176

W

Water management 142

Weed control 99-102, 125-136

West African Shorthorns 188

White leghorn 177

Z

Zinc 103, 110, 154, 160, 164, 196

Zoonotic diseases 180, 181